

EDUCATIONAL BIOLOGY

AMERICAN TEACHERS COLLEGE SERIES

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EDUCATIONAL BIOLOGY

THE CONTRIBUTIONS OF BIOLOGY
TO EDUCATION

A Textbook for Teachers' Colleges and University
Schools and Colleges of Education

BY

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To My Several Excellent Teachers,
from the First Grade to the University



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PREFACE

This book is the outgrowth of a course called Educational Biology, given fifty-two times by the writer during the past eighteen years at the State Teachers' College at West Chester, Pennsylvania, at the Western State College of Colorado (a state teachers' college), at Gunnison, and at the State Teachers' College of Colorado at Greeley. Indeed, since 1911, in both of the latter institutions educational biology has been required as a "core subject" for all students graduating from the two-year curriculum with the teacher's life certificate and also for those graduating from the four-year curriculum with the bachelor's degree which carried with it the teacher's life certificate for the secondary schools of Colorado. Since 1926, a similar course has been required in the Pennsylvania state teachers' colleges.

It has long been recognized by educators and biologists that certain well-established biological facts, principles, and laws may serve as a background for the understanding of the child and as a basis for the solution of many teaching problems. Until very recently, however, no one has attempted to collect, select, interpret, and organize these facts and laws in book form.

It is the hope of the writer that this book will influence other teachers' colleges and schools or colleges of education to put into their curricula a course (or courses) in educational biology. This course should be placed early in the curriculum of the prospective teacher, preferably in the first year of study. It should serve as a basis for the intelligent study of principles of education, educational psychology, educational sociology, philosophy of education, and similar courses. It should also form a substantial basis for the more specific courses in nature study, elementary science, and health education.

The book is intended as a text for one semester or quarter of work. It is not intended as a laboratory course, although

demonstrations should accompany the recitations and lectures whenever possible. Since there are few instructors highly trained in both education and biology, it is hoped that this work may serve as a convenient text for teachers whose major training has been in either field, until such time as a sufficient number of specialists in educational biology are available.

Because the subject-matter for this course has been drawn from many different divisions of biology, it is obvious that certain imperfections may occur. To avoid these as far as possible, care has been taken to have each chapter read critically by a specialist in the field which it concerns. It is hoped that in each field both the latest knowledge on the factual side and the best judgment on the side of hypothesis and interpretation will be adequately presented.

The writer takes upon himself full responsibility for all errors that may occur, and invites further criticism from specialists in any of the fields treated.

It is almost presumptuous to attempt to cull from the many divisions of biology the facts that have the most important bearing on education. The writer dares to do so only because he has been attempting this very thing in teacher-training institutions for nearly eighteen years. In this connection it may be permissible for him to say that he holds degrees in the fields of both biology and education. To apply biological facts and principles to education, wherever possible, has been a chief interest for many years.

J. C. J.

STATE TEACHERS' COLLEGE,
WEST CHESTER, PENNSYLVANIA,
January, 1930.

EDITORS' INTRODUCTION

An acquaintance with the basic principles of biology may be regarded as an indispensable background for an adequate understanding of the larger problems of education. Indeed, modern educational theory rests at basis upon the distinction between organic evolution and social evolution. To appreciate the significance of this distinction and to appreciate the place of education as a primary factor of social evolution, one must know something of the laws that govern organic life as a whole and something of the forces that brought mankind to the plane of physical development from which the distinctively human advances have been made.

The study of biology should serve, too, as a preparation and background for the study of psychology. Modern psychology, like modern educational theory, makes large use of biological principles and postulates. For example, a chapter of educational psychology that has come sharply into the foreground during the past twenty years is that which deals with individual differences, their significance and their measurement; and individual differences hark back to fundamental biological laws.

Nor do we lack more direct and specific applications of biology to the problems of teaching. Among the studies and activities of the elementary and secondary schools none transcend in importance those that are now commonly grouped under the general head, "health education." To teach the health studies well and to direct health activities successfully one should understand the fundamental laws of health and appreciate their significance. At basis these are biological laws.

Finally it is generally agreed that every teacher, whatever his own specialized field of instruction, should have at least a speaking acquaintance with all of the major fields of human knowledge. He should know the outstanding facts and princi-

ples and postulates of each of these fields; and he should know something of the methods through which the facts have been accumulated and the principles established; he should know something about the men and women who have made the most substantial contributions to human progress. The desideratum last named gives a peculiar significance to biology as a foundation course for teachers. For the inspiration of youth, the heroes of science may well be catalogued with heroes in other fields of human achievement and the development of the biological sciences has been a series of real adventures in which some very interesting men and women have played a dramatic part.

The term "Educational Biology" should not carry with it, then, a narrow interpretation. It simply means that the facts and principles of biology that are of greatest significance to the theory of education and the practice of teaching are given major attention. These facts and principles, however, certainly include those that are important from the broadest human point of view.

The editors are very fortunate in the fact that Dr. Johnson consented to prepare this text. For many years Dr. Johnson has conducted a course in educational biology for prospective teachers. He knows intimately the needs of such students. He is, too, a competent biologist. As evidence of his keen desire to make his book thoroughly trustworthy, he spent a sabbatical year in advanced study and in conferences with outstanding authorities in the various biological fields, and he has had each chapter read and criticized by one or more specialists in the field that the chapter represents.

J. A. H. K.

W. C. B.

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EDUCATIONAL BIOLOGY

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CHAPTER I

INTRODUCTION

"It is necessary for us as teachers to take the biological point of view in all our thinking and to seek our educational philosophy in the laws of growth."—LEWIS M. TERMAN.

The science of education had scarcely made a beginning before psychology was called upon to offer its contributions and to solve some of the many problems arising, with the result that at least one course in educational psychology or in general psychology, is now "required" by practically every teacher-training institution in the United States. This is as it should be, since only the psychologist is sufficiently well informed to give accurate and expert advice in certain important fields of education.

Likewise it has been recognized that sociology has important contributions to make to the science of education, and there are few professional schools for teachers that do not offer a course in educational sociology or in general sociology. Almost every educational problem is social as well as individual in nature and the social aspects of education are being increasingly emphasized.

For at least a generation many students of education and many students of biology have believed that biology has much to contribute to the growing science of education and to the art of teaching. In fact, many professional schools for teachers have had at one time or another a course devoted in part, at least, to some of the biological aspects of education. These courses have been called by a variety of names and often com-

bined with subject-matter other than biology. Perhaps the most common names for such courses have been: "Biological aspects of education," "Biology as applied to education," "Bionomics," and "Educational biology." The last name seems the best, since it is a brief and accurate description of the content and purpose of the course, and is in keeping with recent developments in the fields of psychology and sociology as applied to education.

Just as educational psychology and educational sociology are not new kinds of psychology and sociology but only the significant parts of their respective fields that contribute most to education, so educational biology is not a new kind of biology but rather a selection of the important facts, principles, and laws of biology that have a bearing on education.

Wherever possible, applications both direct and indirect will be made to the science of education and to the practical work of teaching. However, many facts and laws must necessarily be stated and demonstrated before the proper foundation is laid for the establishment of a principle in the field of education or in the art and science of teaching. This course is intended

neither as a "methods" course nor as an "academic" course; rather it seeks to provide a general biological basis for the better understanding of the child and of the various problems involved in the teacher's work.

It is the writer's belief that an adequate background for the work of teaching and the science of education must include an understanding of educational biology, educational psychology, and educational sociology. Upon this

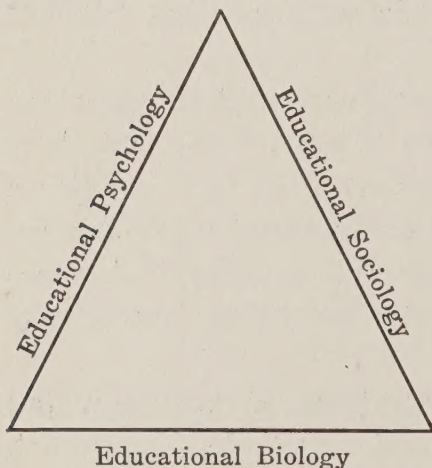


FIG. 1.—Three foundational courses for educational theory and practice.

threefold basis sound educational thinking may be developed and a correct educational philosophy projected. With such a

basis courses in educational theory and practice can and will mean more to the prospective teacher.

Educational biology is placed at the base of the pyramid, not because it is of greater importance than educational psychology or educational sociology, but because it is basic to the understanding of these subjects. Both the sociologist and the psychologist appreciate the value of a biological background. The child must first be understood as an animal with human potentialities before he can be properly understood as a distinctively human animal, and both of these points of view are necessary before he can be understood as a social unit.

It has been proclaimed from the desk, the pulpit, and the lecture platform that the *child is first of all* a thinking animal, or a social being, or a moral individual, when as a matter of fact he *is not, first of all*, any of these, but *distinctly an animal with human potentialities*. The child *is not born moral or immoral, but unmoral*. The young child does not think a thing through carefully but reacts to stimuli and experiences more or less instinctively, although perhaps on a higher level than other animals.

The child's reactions and relations within the group are at first very similar to the responses of other social animals. All in all, the child is governed at first by instinctive urges and desires that are not essentially different from those manifested in other vertebrates. The inherent possibilities of the child are much greater than those of any other species; but these higher manifestations have an animal basis.

It is an old saying that "the proper study of mankind is man." This presumably means that the only good and true way to find out anything about the human being is to study the human being, by far the most complex of all living things. Adequately to know mankind, however, one must study the simpler organisms out of which every living thing is made. No correct conception of the child is possible unless we first learn about the function and structure of the unit of life,—the cell—found in all forms of life, whether high or low, plant or animal, including human-

kind. It was Samuel C. Schmucker who wisely said, "The child is just many simpler organisms complexed into one." There can be no doubt that every prospective teacher will profit greatly by such a study, for then, and only then, will he be able to understand that the child is truly "wonderfully made."

The subject-matter of this text has been carefully selected with the needs of prospective teachers always in the foreground. The interpretation of the facts, principles, and laws of biology in their relations to the science and art of education are necessarily somewhat original with the writer. In these interpretations there will inevitably be something of the theoretical, and for these theories the writer must take all the blame, or the credit if perchance they may represent worthy suggestions.

The child is the product of an incalculable period of time, of a long line of ancestry, and is a very complex being with strong animal tendencies and great human possibilities. The aim of this book is to promote a better understanding of the child biologically, so that his education may be better adapted to his nature and his needs.

QUESTIONS

1. Why do you think the science of educational psychology was developed and was taught in schools of education, normal schools, and teachers' colleges before educational sociology?

2. Why do you think educational sociology was taught in these same institutions before educational biology?

3. Before proceeding further with this course, can you now think of one reason why the biological point of view is a necessary part of the teacher's educational philosophy?

4. Why are all three—educational psychology, educational sociology, and educational biology—necessary in order to have an adequate background for teaching and the science of education?

5. How do we know that the child is born unmoral, not moral or immoral?

6. Name some trait or characteristic, if any, physical or mental, of a child that is totally different from those found in the higher animals below the human level.

7. Name a number of traits or characteristics, physical or mental, of a child that are foreshadowed in the lower and higher animals.

CHAPTER II

THE CHIEF SUBDIVISIONS OF BIOLOGY

Educational biology in relation to these subdivisions.

Biology is a broad subject, usually divided into two main divisions—zoölogy and botany. Both of these divisions have many subdivisions, each of which has become a special field of study and research.

In the attempt to pick out the facts, principles, and laws of biology that have an important bearing on education, many of these subdivisions will be called upon to yield some of their outstanding contributions. The more important subdivisions that will be drawn upon for facts or laws or both are: embryology, cytology, histology, morphology, paleontology, anthropology, taxonomy, ecology, animal and plant geography, physiology, anatomy, psychology, pathology, bacteriology, protozoölogy, parasitology, entomology, evolution, euthenics, heredity, eugenics, and experimental biology.

There are other subdivisions of biology, but most of them are either so remotely related to the subject of education or so highly specialized as to offer little of value to the prospective teacher.

Not all of the above-named subdivisions will be discussed under their respective headings in separate chapters; some will be referred to in the treatment of other topics as the occasion demands.

EMBRYOLOGY is that part of biology which deals with the development of the individual before birth or "hatching." There are certain important facts of this "prenatal" development, particularly of the child, that every teacher should know.

CYTOLOGY deals with the ultimate units of living things—cells.

It is particularly concerned in this book with the growth of the various somatic or body-cells and with the complex mechanism of inheritance as embodied in the germ-cells,—that is, the cells through which life is transmitted from one generation to the next.

HISTOLOGY considers the connected aggregates of cells in tissues. It is concerned with the tissues of the body,—such as

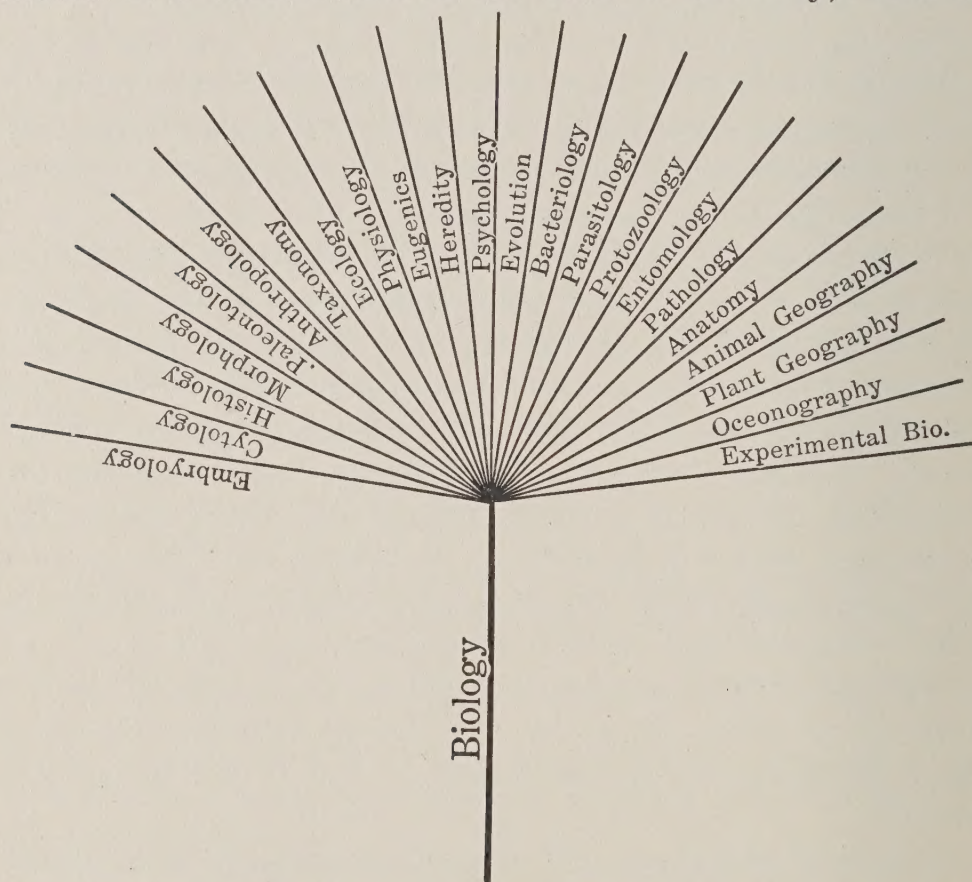


FIG. 2.—Important subdivisions of biology.

the bony tissue, the muscular tissue, the nervous tissue—and with their adaptations to the functions that they perform.

MORPHOLOGY is concerned with the structure of animals and plants. Comparative morphology and its applications will be stressed in this book. As the term implies, comparative morphology compares the structures of different kinds of animals and plants.

PALEONTOLOGY is a study of the remains of plants and animals that have been preserved in the soil and rocks as "fossils." Man's ancient history and the ancient history of other living things as well are not without important bearings upon educational theory. The problem of determining the age of the earth and the duration of life on the earth is approached through the study of paleontology.

ANTHROPOLOGY is the study of the life history of the human race and is linked closely with paleontology.

TAXONOMY is the science of classification based on structure. By structure we mean the make-up and arrangement of cells, tissues, and organs. From this science we learn the how and why of classification. Taxonomy throws important light on the position of man in the animal kingdom.

ECOLOGY is a comparatively new science and is concerned with the relation of life to its environment. This is a most important topic for education since it deals with the effects of the environment and of the animal and plant associates on the individual.

ANIMAL AND PLANT GEOGRAPHY is also a comparatively new science stressing the influence of the environment on the distribution and the adaptations of animals and plants.

PHYSIOLOGY deals with the functions of the organs, tissues, and cells of the body. By function is meant the normal and special rôle that any part of a living animal or plant plays in the life of the organism as a whole.

ANATOMY has to do with the structure of the body. Certain facts about structure are essential to an understanding of physiology.

PSYCHOLOGY is the science of mind. Since the study of psychology is usually required of all prospective teachers, we shall be concerned with this subdivision of biology only to the extent of showing the aspects of man's mind that are expressed in lower forms of life and of describing the bodily structures and functions that underlie mental activities.

PATHOLOGY is concerned with abnormal structures and func-

tions, and is particularly a science of disease. It is important that certain outstanding facts and principles of pathology be known to the teacher.

BACTERIOLOGY is the science of microscopic plant life. It is of vital importance to education since it is so closely bound up with health. Important facts concerning the growth, structure, physiology, and effects of bacteria are emphasized.

PROTOZOÖLOGY, the science of one-celled animal life, is of importance in much the same way as is bacteriology. Similarities and differences between one-celled animals and the cells of the human body are pointed out.

PARASITOLOGY includes parts of both bacteriology and protozoölogy but also applies to groups of animals not dealt with by either of those sciences. It discusses the relation of parasites to health and the effect of parasitism on the host as well as on the parasite.

ENTOMOLOGY deals with one division of animal life, the insects. The dominant forms of animal life are vertebrates and insects. Entomology is of much importance in its applications to agriculture. A knowledge of some of its facts and principles is essential to all who would understand the conditions under which modern civilized life is made possible.

EVOLUTION is the science of change, the history of the steps by which an organism or group of organisms has come to have distinguishing structural and functional characters. Since the idea of evolution has modified very profoundly human thought, it is important that the teacher find out *what has and what has not been proved* about evolution.

HEREDITY is the science of the relation between generations. Its facts have a most important bearing on education. Our whole educational policy is bound to be modified in terms of the facts discovered by expert students working in this field.

EUGENICS is the practical application of the facts and laws of heredity to the human species. Although much has been written about eugenics, the facts are seldom presented in an unbiased fashion. The actual facts the teacher should know.

EUTHENICS is an important science, little heard of, dealing with environment and its effect on life and particularly on the human species. It is essentially a part of ecology. Since organized education represents an effort to control environmental influences, it is obvious that correct conceptions of the effects of environment on the life of the individual and on the species should be known to teachers.

EXPERIMENTAL BIOLOGY, except in a few outstanding instances, is a science of recent development. It is concerned with an attempt, by controlled experimental means, to determine some of the facts and laws of biology. Some of the investigations in this field have an important bearing on educational problems.

In the period allotted to the course in educational biology only a very few of the most useful facts, principles, and laws of these various subdivisions of biology can be discussed. The student must be made fully aware that when this book has been completed, he has touched upon only a very small proportion of the facts that may be profitably studied in any of these various fields.

It is hoped that a general survey of the contributions of biology to education as presented in this book will cause some few outstanding students to continue in this field of work. In professional schools for teachers there is certain to be a strong and steady demand for men and women who will be qualified to teach educational biology. This will mean advanced study both in the field of biology and in the field of education. The road is long, but the reward in the end will make the effort worth while.

QUESTIONS

1. Find out about some subdivisions of biology not listed in this chapter.
2. In what way is a knowledge of some of the fundamental facts and laws of ecology necessary for a proper understanding of human society?
3. How does geographical location influence the number of individuals that can live in a given area, particularly the number of human beings?
4. When and with what man or group of men did the science of bacteriology have its beginning?

5. How has the study of evolution influenced our attitude toward history? Toward government? Toward religion? Toward the family?

6. At this point in the course, which do you think is more important to the child, to have a fine environment or to have a fine inheritance? Or are they of equal importance? If so, show why.

7. Do you think that by experimenting with the lower animals one can or will find out facts or principles concerning man? If so, how or why? If not, why not?

CHAPTER III

TWO BASIC LAWS OF BIOLOGY

The tendency to vary (to be distinct from the group—to be individualistic)—The tendency to be like parents (to be like other members of the group—to be social)—The application of these two laws to the teacher's problems.

In every science, there is a place which may well be designated, "In the beginning." The human being with his finite mind cannot get beyond this point. To be sure this limit is being pushed further and further back as scientific research continues; in fact, it is the chief aim of pure science continually to destroy old frontiers and to create new ones.

In biology there are two laws which might be said to lie at the root of all other laws and facts and which in a certain sense can be said to have been "in the beginning" of life. Fortunately, practically all biologists agree that these two laws are basic since they are obvious to anyone who will stop to consider.

These basic laws of life are: (1) all individuals tend to change, to be modified, to "adapt," to be distinct from the group; and (2) all individuals tend to remain constant, to be like the parent stock, to be like other members of the group.

It is evident that these laws are exact opposites and at first thought it would seem either that both laws cannot operate at the same time on the same individual, or that one law must be of greater importance than the other. Yet, even though they are exact opposites, both are of equal importance and both are operating on the same individual at the same time; in fact, each is absolutely essential to the other. If either law had its sway unchecked by the other, life would soon cease to exist.

If on the one hand the tendency to change, to be modified, to "adapt," were unchecked by the tendency to remain like the

parent stock, there would in all probability be so much change in each individual of each generation in each species that it would soon cease to be sufficiently adapted to its environment and would therefore fail and go out of existence. Individuals in the same species would become so different in a few generations that pollination in plants and breeding in animals would be impossible. It is well known that only individuals who are fairly

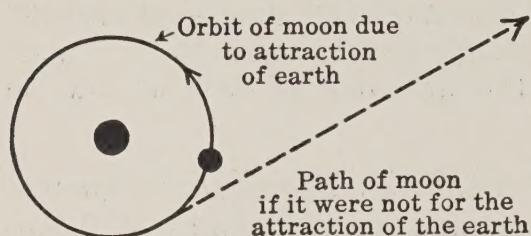


FIG. 3.—Diagram to illustrate the two opposing forces controlling the moon's movement. Somewhat analogous are the opposing forces controlling all life—the tendency to vary and the tendency to be like parents.

similar to one another can interbreed successfully generation after generation.

On the other hand, if the offspring were exactly like the parent, eventually the species would also cease to exist because it would fail to be adapted to the ever-changing environment. To be sure, the fatal day might

be long delayed if the environment changed very slowly, as, for example, on the ocean floor; but even here the death of the species would be almost certain. In fact, the tendency to remain constant, to be like the parent and not change to meet the ever-changing surroundings is the chief reason why *more species in the past have failed, and have completely gone out of existence, than there are species now living*. A conservative paleontologist estimates that at least five times as many species have failed and died out as are now living.

A successful species, whether plant or animal, is one that changes constantly, even though very slowly, to meet changing conditions, but at the same time is held in check by the laws of heredity, which tend to hold the individual and the species true to parental form.

If it were not for the operation of these laws children either would be so different that it would probably be impossible for them to live, play, or learn together, or so nearly alike that there would be no individuality and consequently no personality. In

fact, there would be no such thing as a species which is always composed of similar and yet differing individuals. Progress is possible in animal and plant life only when both laws are operating.

There is inherent in the human species, as in all species, the tendency to be different, to be a wholly distinct individual and at the same time the tendency to remain constant, to be like the parent. Both of these basic laws must be borne in mind if we are to give the right emphasis in the education of children.

QUESTIONS

1. In human beings do you think there is a greater tendency to vary from the parents or to remain like the parents? Does this hold both for physical traits and for mental traits?

2. In which group do you think the tendency to differ from the rest is the more marked, in civilized nations or in savage or uncivilized tribes?

3. From the social point of view, what is likely to happen to an individual who becomes distinctly different from the rest of his group, either in physical or in mental traits?

4. Can you name a modern nation which has seemed to stress more the necessity of remaining like its ancestors than of encouraging individual variations?

5. What is likely to happen to a people who stress the necessity of doing just as their fathers did?

6. What is likely to happen to people who stress the opposite viewpoint?

7. Do the rules, regulations, and laws of our present civilization tend to hamper or to aid the biologically superior child? How or why? What can be done about it?

8. What facts in this chapter, if any, could be profitably taught to children in the elementary grades? In the junior high school? In the senior high school?

9. What facts or principles in this chapter are totally beyond the comprehension of most children in the elementary grades? In the junior high school? In the senior high school?

CHAPTER IV

VARIATION

The human being probably the most variable of all animals—This probably one of the chief reasons why he is the leading animal—Quantitative, qualitative, meristic, and mutative variation—Inherited and non-inherited variations—What variation should mean to the teacher.

As stated in Chapter III, the tendency to vary is inherent in every plant and animal. Not only is it true that everything now living differs from everything else, but the science of paleontology leads us to believe that this has always been so. For all practical purposes we can say that even the very early development of life upon the earth was marked by variation among individuals of the same species.

Nor is mankind an exception to the rule, for it appears that of all living things the human species is in some ways the most variable, and since variation is one of the two fundamental bases for all development and progress, it is possible to understand, partially at least, why the human race is the most highly developed species on the earth.

If one is skeptical of the statement that variation is universal—that no two living things are exactly alike—one need only search for an hour to be convinced that no two rabbits, no two leaves, no two wheat kernels are alike as to size, color, shape, weight. Probably “identical” human twins¹ are as nearly alike as it is possible to find living organisms, but even they show minor differences if examined carefully.

To many individuals it might seem that offspring of the same parents would all be alike at birth, but it is well known that in

¹ Identical twins develop from the same germ-cell and hence have identical hereditary tendencies. This phenomenon will be discussed further in Chapter XIX.

a litter of pups or kittens it is difficult to find two that closely resemble each other in color, especially if the parents are not of pure blood. Theoretically it is possible for offspring of the same parents to differ as greatly in appearance as those from different parents, although actually and usually they resemble each other more. A later chapter on maturation and fertilization will explain why this is possible.

It was once commonly believed that environmental influences, such as home surroundings, schooling, and the like, caused variations in the individual which were passed on from generation to generation by physical heredity. It may be conceivable that, in the long run over hundreds of thousands or millions of years, minute accumulations due to environmental effect influence one's physical inheritance. This has not been proved, however, and it is certainly true that so far as a few generations are concerned, no evidence of the hereditary effect of the parents' or grandparents' environment is noticeable in the offspring.

For example, the sun's direct rays striking the skin of the Caucasian will in a few days darken his skin. If he continues his exposure to the sun, this modification of the color of his skin will persist. But this change in color of the skin does not in the least modify the skin color of his children. They, too, must come in contact with the sun's rays if they are to become brown. Inheritable variation is much deeper than that, as we shall see later.

It has been emphasized that progress in the development or improvement of species is due to variation, but it should be borne in mind that *extreme* variations among animals or plants are seldom continued into the next generation for lack of a similar mate in the same region at the same time. Ordinarily variations are minute and get lost in the herd by mating with the average of the species. Variations are usually small, revolving around a very slow-moving center, rather than extreme and developing rapidly into a new species.

For convenience, variations may be divided into four types: *quantitative*, *qualitative*, *meristic*, and *mutative*. The first three

may be grouped together as *continuous variations* while the last is often called *discontinuous variation*.

Quantitative Variation. Quantitative variation is the most obvious to the greatest number of people. Whenever we describe the size of an animal or plant, we are forced to say that it is "about" so large, or that it is "larger" or "smaller" than some-

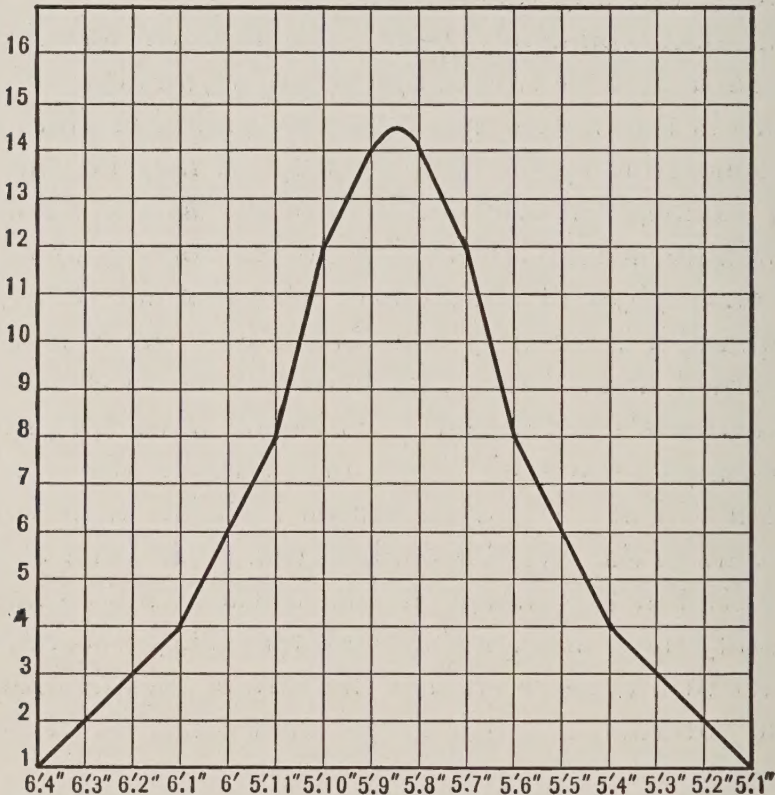


FIG. 4.—Diagrammatic drawing of a typical curve illustrating height variation in one hundred men.

thing else. If we are describing the maximal size of any species, we must always allow for those that may be still larger than the known maximum. Likewise if we are stating the minimal size of a species, there is a possibility that there may be one or a few individuals falling below the known minimum. To illustrate, if one is asked how tall is a human being, one might be inclined to say from four feet to six feet, six inches; yet everyone has heard of dwarfs shorter than four feet and giants taller than six feet,

six inches. Indeed, neither the minimum nor the maximum, theoretically at least, can ever be reached. No one knows just when a still smaller or still larger individual may be produced in any species.

If the height of a large number of human beings, the length of robins, or the weight of pigs is measured at a given age, the measurements can always be distributed in a certain way, as illustrated in the "normal distribution curve." On either end will be the low line representing the few very small or very large individuals. The curve will gradually rise, portraying the fact that a still greater number of individuals are just a little larger than the smallest or smaller than the largest, and finally in the center will be the big group representing those of average size.

Even such small things as tuberculosis bacteria or insect eggs are found to vary in size. The same is just as true of large animals and plants, such as elephants, whales, and redwood trees.

Qualitative Variation. Qualitative difference may be expressed in many ways—by hardness, speed, endurance, fineness of hair, acuteness of vision, brain power, and the like.

In countries where the winters are cold or the summers hot and dry, a few seeds of a given species will survive, while the majority may fail to come through these unfavorable seasons. The result is that the region in question is populated by the seeds of those few that are hardier than the rest.

Quantitative differences are usually quite evident, but qualitative variation is seldom so easy to measure or demonstrate. To be sure, two cows of the same age and breed may differ greatly in the quality of milk produced, as regards butter fat. Two hounds may look very much alike, but the quality of their running may be very different, as regards speed. Plants may differ as to their ability to withstand drought or cold, and this variation is usually regarded as a qualitative difference.

Qualitative differences in speed may be observed in a pack of dogs chasing a rabbit. If the race is a long one resulting in favor of the dogs, the one to catch the rabbit will, of course, be the one

that can run the fastest for the distance necessary to overtake the rabbit. Conversely, several rabbits may be scared up by one dog, but the fastest ones may get away because of their greater speed. The slowest one may be caught and killed, and obviously there will afterward be no offspring there.

The quality of endurance could also be illustrated in such a race, if the race proved to be an exceedingly long one. Occasionally this particular qualitative difference may be the deciding factor in the preservation of the individual and its offspring.

Such traits as qualitative difference in fineness of hair or acuteness of vision can be illustrated by the sheep and the eagle. Sheepmen are well aware that certain individual sheep have finer wool than others, and by continuous selection of those having the desired quality of wool, new breeds of sheep have been produced, the coarser-wooled individuals being killed for mutton before propagating their kind to any great extent. It is also reasonable to suppose that eagles differ in the keenness of their eyesight. Those keenest in discerning moving objects on the ground, such as rabbits, ground squirrels, and prairie dogs, would be able to secure food more surely and regularly and in the long run would be the only ones to leave offspring.

Mankind, gives us the clearest examples of qualitative differences. Even in the human species, however, such differences are harder to point out than quantitative differences. The inability of certain people to digest certain foods, such as honey, butter, or even milk, is well known. Some people can get much more nourishment out of a given amount of food than others.

Even more significant than these qualitative physical differences are the mental differences. It is a well-known fact that children and adults differ mentally. We base our judgment of others largely on this factor. It is true that good or poor grades in school may be due to hard work or to laziness as the case may be, as well as to native ability, but the latter probably plays the larger part in determining the grades that one will receive. The entire testing movement, so prominent in most school systems

at present, is largely built upon the fact that children differ qualitatively—in the ability to learn and to think.¹

Meristic Variation. That variation occurs not only among individuals of the same species but within the individual himself is evident if we examine any individual carefully. All the higher types of animal life are bilaterally symmetrical—that is, they tend to be alike on both sides. If a line be drawn from the center of the forehead down to the tip of the nose, through the center of the breast-bone and on to a point between the ankles, it is found that externally, at least, we are bilaterally symmetrical—apparently alike on both sides. If, however, we compare carefully the two eyes, eyebrows, ears, arms, hands, and feet we find that they always differ in minor details, sometimes very noticeably.

Sometimes the difference in the sides of the face is so great that if a cast is made of the left side and another of the right side, one would scarcely believe that they represented the face of the same individual. To prove the fact of facial variation, one need only examine one's self carefully before a mirror.

Differences of this type in the individual are sometimes called *meristic variation*.

Mutative Variation; Discontinuous Variation. Mutation or mutative variation is a type of variation that occurs occasionally, perhaps more often than suspected, but even then only once in thousands or millions of cases. A true mutation is a variation so great that the offspring of the variant vary around a new center, not around the old one from which the variant rose. Good examples of mutations are evening primroses, Colorado potato beetle, Ancon sheep, Merino sheep, hornless Hereford cattle, copper-beech trees, and hairless dogs.

Some outstanding biologists, notably Hugo de Vries, have

¹ The writer cannot refrain from one precaution to testing enthusiasts—namely, that children should not be told that they are not natively as bright as others. They have sufficient handicaps already without the addition of this discouragement. Often the individual not so mentally alert as others may amount to more in the end, because of his persistence, honesty, and hard work. These factors must never be overlooked by the teacher.

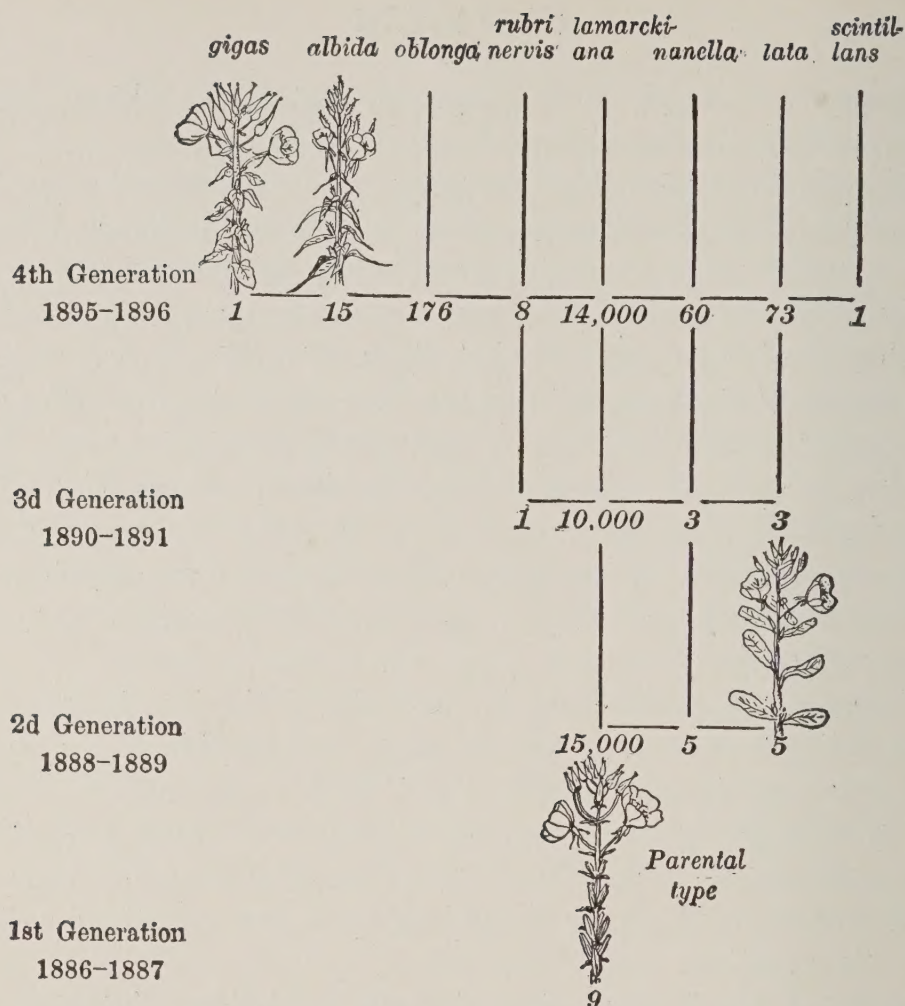


FIG. 5.—*Mutation in evening primrose*. In 1886 Hugo de Vries gathered the seeds from a number of evening primroses (*Oenothera lamarckiana*) which he found growing in a vacant lot. These plants are native of North America, and probably escaped from some Dutch garden. From seeds thus obtained about 15,000 ordinary *lamarckiana* plants were grown, and in addition five peculiar dwarfed individuals (*nanella*) and five with broad leaves (*lata*). These two sets were different from the parents as well as from any other known varieties of *Oenothera*. Later these forms appeared again in very small numbers from large sowings of *lamarckiana* seeds (third and fourth generations). In the third sowing (1890) another new form appeared, having reddish veins (*rubrinervis*). In the same manner new types have appeared in each succeeding generation and some of these types appeared anew several times. By means of careful breeding it was possible to preserve the new qualities, and to recombine them with one another and with the contrasting characters of the parent type according to the Mendelian principles, discussed in a later chapter. (From Gruenberg's *Elementary Biology*, by permission of Ginn and Company, publishers.)

held that all permanent changes, save minute ones, are brought about by the process called mutation, and that only mutations can explain the rise or origin of new species. That big jumps occur occasionally in certain species seems to be well authenticated, but whether evolution in its main trend has taken place that way is a disputed question. Most biologists still believe that small variations, resulting primarily from maturation and fertilization, plus long isolation and adaptation in a new environment, are sufficient to cause new varieties and species.

As stated in an earlier paragraph, mutation is also called *discontinuous variation*, since there seems to be no evident connection between the two generations. New varieties have been produced at will in some species by scientific breeding, and have been explained by "Mendel's Law," which we shall discuss in a later chapter. (See Chapter XXI.) It is possible that this law may be found to be the means of explaining all mutations, once all of the numerous hereditary factors in a given species become known.

Even though the fact has been emphasized that no two things are exactly alike, the conclusion should not be drawn that children are so different that they cannot sometimes be considered in groups and that certain group generalizations cannot be made. As a rule all members of a species are very much alike on all major points and differ mostly in details. This is just as true of human beings as of any other form of life. At the same time, the fact that children are usually much alike on major points is no reason why each child should not be considered and treated as a distinct and different individual whenever significant differences appear.

We shall close this chapter by reëmphasizing the fact that variation is universal in all living things; that every species must either change gradually or fail sooner or later because not adapted to an ever-changing environment; and that if the change is too rapid, it is just as fatal to the species as if it is too slow because it also is likely to involve maladjustment. Ordinarily to be successful, a species must



Fig. 6.—*Horticultural varieties of the wild cabbage*. A, wild cliff-cabbage, hypothetical ancestor of numerous modern horticultural forms; B, broccoli (leaves and flowers both used); C, kale; D, kohlrabi; E, Brussels sprouts (lateral buds used); F, common cabbage (a highly developed terminal bud); G, cauliflower (flower-buds used). (From Gager's *Fundamentals of Botany*, published by P. Blakiston's Son & Co., Inc., Philadelphia.)

change gradually, continuously adjusting itself to its environment.

This is obviously true of the individuals that comprise the human species. The human environment is one of constant change. "To learn" is to make some change that will meet a new demand of life. To teach is to guide and direct appropriate changes on the part of the learner. The changes brought about by learning, however, must not be confused with the changes brought about by variation. The differences between these two types of change are fundamental to educational theory; they will be discussed in a later chapter. (See Chapter XIX.)

QUESTIONS

1. Why do you think it is impossible for two living things to be just alike?
2. What reason can you give for assuming the possibility that mankind may be the most variable of all species?
3. Why do most people believe that the environment and life-experiences of an individual cause variations in the germ-plasm?
4. Can you show how in one sense qualitative variation is really very similar to or almost a part of quantitative variation?
5. How does bilateral symmetry in plant and animal life differ from radial symmetry? From asymmetry? Why are all the higher forms of animal life bilaterally symmetrical?
6. Why is it impossible to give a definition of a species that fits every individual of that species?
7. Suppose we could define a species exactly, how long would this definition hold?
8. What topics in this chapter, if any, could be taught to children in the elementary grades? In the junior high school? If any of these topics could be taught, would it be wise to teach them on one or another of these educational levels? Why or why not?

CHAPTER V

NATURE'S METHOD OF SELECTION

Is success or failure of individuals and species the common rule out in nature?—The struggle for a place in nature (struggle for existence)—The survival of the best (survival of the fittest)—Applications of these laws to man—How these laws should be modified in order to benefit mankind, particularly children—The training of children to make them *fit to survive*.

The year 1859 marks the beginning of modern ideas concerning “natural selection,” “the struggle for existence,” and the “survival of the fittest.” It was in this year that Darwin’s book, *The Origin of Species*, appeared. Darwin’s great contemporaries, Alfred Russel Wallace and Herbert Spencer, were also active in coining and explaining the last two phrases. Very few phrases contain so much food for thought and are misused to a greater extent when applied to human beings, than these three. As teachers and prospective teachers let us examine them carefully in the light of modern science, not in the heat of debate.

Prior to Darwin’s book, *The Origin of Species*, no explanation was made as to why certain individuals out of a herd, a litter, or a group of seeds, for instance, survived and why the majority died before maturity or (in the case of seeds) failed in some cases even to germinate. Darwin was the first to offer a reasonable explanation for this phenomenon and also to give a reasonable hypothesis to account for the survival of new species.

Although the idea of evolution had been suggested many times, even as far back as the early Greeks, yet no one could offer a reasonable explanation as to the how or the why. Both Darwin and Wallace were greatly influenced in their thinking by a book dealing with population written by Malthus. It should be mentioned here that the theory of natural selection was worked

out by Darwin and Wallace, both reaching their conclusions at about the same time. When each learned what the other had done, each urged the other to publish the results and take the credit for the discovery—one of the finest examples of courtesy and generosity in the history of human progress. Darwin, because he had worked much longer than Wallace on the problem, was finally persuaded to do the writing, and the book came from the publishers in 1859.

Although the material for the book was the result of more than twenty years of hard labor and observation, and although Darwin was well known as a keen thinker, a most careful observer, and a very severe critic of himself and of his own work, the influence of the book has been due primarily to the new principle which it set forth—the principle of natural selection.

In the *Harvard Classics*, edited by the late President Charles W. Eliot of Harvard, Darwin is the only person to be recognized by the inclusion of two books. These are *The Origin of Species* and *The Voyage of the Beagle*. *The Voyage of the Beagle* is an account of a trip around the world, lasting five years, which Darwin took as a young man. He visited many islands, studied marine life in both the Atlantic and Pacific, and made a prolonged study of plants and animals on the west coast of South America. On this trip, among many other things, he noticed that the islands near the mainland had plant and animal life almost identical with that of the continent; but that the farther removed the islands were, the more the plant and animal life became unlike that of the mainland and of other islands. These facts doubtless influenced Darwin to formulate the general statement that if animals failed to adjust themselves to their environment, they failed in the battle for individual existence and eventually in that of their species.

Natural selection, in its simplest terms, is nature's method of selecting out of a group the few individuals that will survive and reproduce the species. Every species, whether plant or animal, produces during its lifetime many more seeds or offspring than can possibly survive.

If we consider the common tumbleweed of the plains region, for example, we find that it ordinarily produces annually more than a thousand seeds. If each of these matured and in turn produced one thousand seeds, tumbleweeds, in less than ten years' time, would cover the entire land surface of the globe. Apparently, however, there are no more tumbleweeds to-day than existed ten years ago. Why not? What holds them in check?

If each of the four eggs ordinarily found in a robin's nest hatched, and if each of the four young robins came to maturity, mated, and in turn helped to produce four other eggs, and if this process were repeated indefinitely, it is obvious that the earth would shortly be crowded with robins. Consider, also, the fact that some of the adults of the preceding year would be still alive; indeed, some believe that robins live about four years, thus allowing for the possible production of twelve eggs during a single lifetime. Why are there not more robins now than a few years ago?

Many fish produce several thousand eggs each season; if they all lived and reproduced in similar fashion, the ocean would be completely filled in a very few years. Jordan and Kellogg¹ state that the quinnat salmon of the Columbia, when four years old, ascends the river, lays four thousand eggs, and dies. Assuming that half of the eggs should hatch into males, the other half into females, and that all of them came to maturity from generation to generation, there would be in fifty years 16,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000 salmon. There would be no room for them in all the rivers of the North nor in the waters of the sea.

Authorities on elephants assert that each pair of elephants produces about six young during a lifetime. They start to breed at about thirty years of age and live to be about a hundred years old. At this rate there would be in 800 years not fewer than 19,000,000 elephants alive, descendants of one pair. In 800 years

¹ Jordan, D. S., and Kellogg, V. E., *Evolution and Animal Life*. D. Appleton and Co., 1907.

more it is doubtful if there would be standing room on earth if it were possible for all the offspring to live and reproduce in like ratio. If it is possible theoretically for the slowest breeding animal of all, the elephant, to cover the earth's surface in a few centuries, one need only imagine what would be the condition, with animals that bear many young each year, if all the offspring could come to maturity and reproduce generation after generation.

Most plants produce hundreds if not thousands of seeds each generation, but even a plant producing only two seeds each year would have in twenty-one years, 1,048,576 descendants if all of the seeds sprouted and matured.

If the calculation is transferred to the field of bacteria which divide by binary fission,¹ it is theoretically possible to have at the end of twenty-four hours over 281,000,000,000,000 offspring, provided that division occurred once every thirty minutes. There would be enough, if placed end to end, to reach around the earth nearly thirty times, even though 6,000 of these bacteria placed end to end measure only an inch. But of course no living organism gets an opportunity to develop as rapidly as that, not even the bacteria and protozoa, except, perhaps, for brief periods of time. Something is always holding the number of seed or offspring down. What is it?

It was a question of this sort that was raised in the minds of Darwin and Wallace when they read the book of Malthus on population, for Malthus emphasized the same possibilities in the reproduction of the human species. What is it that keeps any single species from overrunning the earth? The tendency of every plant and animal is to keep its kind in existence and to spread its kind (species) as far as possible. Since there is only a certain amount of space for living organisms to occupy, it is obvious that some kind of struggle must ensue.

This "struggle for existence"—for a place in nature—may take on many aspects which, regardless of the method, result in the long run in the survival of those that are "fittest" to sur-

¹ That is, by division of each individual into two parts.

vive. Keep in mind that the phrase, "survival of the fittest," does not necessarily mean survival of the fiercest. In fact, actual fighting by claws, beak, teeth, or horns for a place in nature is comparatively uncommon.

In the plant world, the struggle for life is usually a very slow battle for light, for moisture, for food. In early spring one may notice several hundred small plants on a square foot of soil; on reëxamination in the fall one may find only a few or sometimes only one that survived. The individuals surviving may have come from the largest, the hardiest, or the fastest growing seeds; or perhaps there may have been some factor unknown at the time, working to their advantage. Other things equal, the largest seeds out of a given species would have the best chance to survive since they would produce the largest embryo plants to start with and would soon have the advantage of being able to shade their neighbors more and more each day, eventually causing the death of those shaded. Hardiness is more subtle and consequently more difficult to define; nevertheless, it is often the deciding factor in certain climates, especially on early spring days, late in the fall, or in winter. Seeds that sprout and grow faster than their neighbors obviously gain a slight advantage in a short time. It should be kept in mind that all green plants must have light or else they will perish. The dead limbs at the bottom of, or near the center of, forest trees are the result of absence of light; grown in the open, many of these limbs would live. In addition to these three factors—size of seed, hardiness, and rapidity of growth—there are doubtless scores of others which must be accounted for if one would understand why in the plant world certain individuals or species fail while others succeed.

In the animal kingdom fleetness of foot may determine what individuals or species will survive, as in the case of rabbits or antelopes. Perhaps keenness of vision may determine the winners in the race for life as in the case of hawks and eagles, or perchance it might be sharpness of claws as in the case of squirrels or cats. The color of the individual may also sometimes be

the deciding factor, particularly if the animal matches its surroundings especially well, as do white-tailed ptarmigans, night-hawks, and whippoorwills.

Sometimes the ability to fight decides, if not which individuals shall live, at least which shall reproduce the species, as in chickens, walruses, and deer. In the majority of cases probably the most vigorous males get the chance to reproduce their kind, and thus the species is kept at its best physically. For the weakest to be successful would be fatal to the species in a very few generations.

In mankind the struggle for existence, for life, results usually in the survival of the fittest, but fitness is a different thing in different races and nationalities and at different stages of civilization. Among the North American Indians, fitness is largely conceived of in terms of large physique, bravery, and fighting power, while in civilized countries, mental development is usually the factor that determines the individuals who will forge ahead, if not those that actually survive. Between these two extremes one will find almost every variety of fitness.

Man is the only animal species in which the weak are protected and have the opportunity to reproduce their kind. Due to the great skill of physicians, surgeons, and sanitary engineers, the weak survive where they might otherwise perish early in life. Since they are allowed to continue their kind from generation to generation, their number is increasing faster proportionately than that of the healthy. Although we have millions of specimens of human beings who are very nearly perfect, yet it is doubtful if any other species has so large a percentage of weak, sickly, crippled, or diseased individuals. Although the weak are saved by the millions each year by our skilled physicians, in the long run even they die out in a few generations since they seem to be unable to produce sufficiently vigorous offspring. We read often of the last survivor of a family that has been represented in positions of prominence for generations or centuries.

From reading or conversation one may gain the impression that success for the individual out in nature is the usual thing;

but the exact opposite is the case. In the quinnat salmon of the Columbia river, on the average only two eggs out of the four thousand laid by the female come to maturity and produce in turn other quinnat salmon. The other 3,998 fail to come to maturity for a variety of reasons.

The robin probably produces about twelve eggs during its lifetime, but an average of only two eggs hatch and come to maturity, producing other eggs. The death rate is here in the ascendant, ten to two. Even in the slowest reproducing animal of all, the elephant, only two of the six young elephants born come to maturity and produce other young.

Most plants produce, in their wild state, several hundred seeds; but even if unmolested by mankind, only one of these on the average comes to maturity and produces other plants. Even a bacterium which can increase in number very rapidly under certain conditions is represented approximately by only one offspring in the succeeding generations.

The rule covering all of the above-named cases and all other species, save man himself and the animals and plants he has domesticated or protects, is that on the average over a period of years, only as many seeds or offspring come to maturity and produce others of their kind as it took individuals to produce them. This means that among the animals two and only two survive out of the young born or hatched, and in most plants one and only one seed survives on the average out of the seeds produced by a given plant. This rule holds true regardless of the number of seeds or offspring produced, even though they may number more than a million as with some eels, codfish, and cottonwood trees, or only six as with the elephants.

The reader may well ask how we know this to be true since no one has ever attempted to count exactly the seeds or offspring of even one species where the numbers are large. The truth of the statement is comparatively easy to prove even though no one has attempted to make an exact count.

If an average of less than two survived among the animals, the species would soon become extinct, since there would not

be enough offspring each generation to replace the parents. In each generation the adults would therefore become fewer and fewer. If an average of more than two animals continually survived, the world would soon be crowded with one species, and we know that no species, save those that man cultivates, protects, or domesticates, increases perceptibly in numbers for any great length of time. By and large, the rule holds good for all plants and animals. Only where animals or plants may be invading a new territory or in exceptionally favorable years, are they increasing in number. Only where a species is failing to hold its own, is it decreasing in number. In a century of time very little variation is likely to take place, unless man interferes.

It may be well asked why it is necessary to have so high a death rate. Why must the great majority of individuals in any given species fail? The answer is that there must be an excess of seed and offspring to produce enough food to keep other species in existence. If the female rabbit produced only two young during her lifetime, there certainly would be no rabbit for the dog or the eagle to eat. If they did eat rabbit one year, there would be none in succeeding years, which would amount to the same thing as far as the continuation of the species is concerned.

If the wheat and radish plants produced just one seed each, there could be no flour for bread or radishes for the table. If the cow gave birth to only two young during its lifetime, there could be no veal and little beef for man. If the hen laid only two eggs, there could be no eggs for cooking or eating purposes. If the oak tree produced only one seed, there could be no acorns for squirrels to eat. In fact food would be unavailable except at the risk of the destruction of the species. *Food is the excess of seed or offspring, resulting from the process of the struggle for existence and the survival of the fittest.* Usually the weakest or unfit are used first as food. Even though we refuse to admit that the doctrine of excess in nature results in the survival of the fittest, yet we practice it every time we eat a meal. Only through the production of more seed or offspring than it took individuals to produce them can there be food for any species. Farming and

ranching are possible only because all plants and animals tend to produce an excess of seed and offspring. The farmer or rancher simply exploits this inherent tendency in the interest of the largest or best returns.

Since food for all animal species, including man, is so closely associated with the struggle for existence and the survival of the fittest, it is evident that this struggle will go on as long as animals eat. In the long run the fittest do survive, even though skilled physicians, surgeons, veterinarians, and plant breeders are able to save the weak for several generations. It is indeed fortunate that the best do survive and reproduce the race, for a weak species would soon fail and go out of existence.

The fact that every species tends to spread its kind as far as possible has led to a more or less definite *balance in nature*. The advantage that birds have in possessing wings is balanced to a degree by the large number of eggs laid by some of the wingless insects. Even man with his superior brain power finds in the large numbers produced by many insects almost an equal match in the struggle for dominance. Every living thing seems to have its advantages in some form or fashion, but everything also seems to have its disadvantages. Vines do not have to spend as much energy as trees in producing trunks and limbs since they can lean on or climb trees or stones, and thereby use their energy mostly in producing leaves, flowers, seeds, and fruit. However great this advantage may be at times, vines also run the risk of not finding suitable objects to climb and are thus found trailing the ground to be trodden upon by almost any animal. No species seems to have a monopoly on fortunate adaptations, but in turn all seem to be working under great handicaps. Man is no exception to this rule.

But there is usually a balance in nature for a fundamental reason—namely, food. For example, if mice, rats, gophers, chipmunks, prairie dogs, woodchucks, rabbits, and other rodents increase greatly in number because more or better-timed rains made grass more abundant, then hawks, owls, eagles, badgers, and other forms of life that feed on rodents, would in-

crease in number also. If the well-timed rains prevail for several years, both the rodents and their enemies are almost sure to become numerous; if on the other hand a drought occurs, the rodents are almost sure to decrease in number with the result that there are fewer eagles, owls, hawks, and badgers, since their food supply also has been curtailed.

It is equally true that coyotes, wolves, and other carnivorous animals will increase or decrease in numbers in a given region in the ratio that rabbits or similar animals are available as food. The fact that all animals must get food from plants or other animals makes the numbers of one species depend almost entirely on the prosperity of other species. Again man is no exception to the rule. The number of human beings found on a given island or continent is very largely dependent upon the quantity of food available. That North America never became populous before the advent of white men may have been due in part to the fact that the Indian's food was limited. He had no good milk animal, no good egg-laying animal, and not even a good lard-producing animal. He was destitute, also, of a good wool-producing animal. Nor was he more fortunate with plants, since the New World, out of all the important plant crops, has given us only Indian corn, potatoes, and a species of bean. With the increase of animal and plant foods in North America, due at first to importation from Europe, one hundred forty million people are now able to live on this continent. It is estimated that from Panama to Northern Canada there were only about one and a fourth million Indians before the white man came.

While the balance among species in a given locality is almost always of long duration, it can be upset easily by the introduction of a strange species into a region. There are several well known and classic illustrations of this fact. Perhaps the best is that of the introduction of the rabbit into Australia during the nineteenth century in order to provide good hare hunting for those of English birth. The environment was favorable, enemies were lacking and remained so because of the ocean barrier;

thus the rabbits increased rapidly, quickly supplying the desired opportunities for hunting. So rapid was the increase that the rabbits became a pest, eating the grass, crops, and other foliage. The Commonwealth of Australia now spends several million dollars annually fighting this pest.

The English sparrow is another good example. In England and on the continent of Europe, this bird is not a pest as here, because held in check by its long-standing enemies. Without its natural enemies here, the English sparrow has increased to such numbers that in the course of only seventy-five years it has become by far the most numerous of all birds. When a new species is introduced into a region, the balance is almost certain to be upset, if the new species continues to live and increase in number.

The cottony cushion scale is another classic example. This is a parasite found principally on citrus fruits—oranges, lemons, grapefruit. These trees are not native to America but thrive very well in certain parts. When first introduced, the cottony cushion scale being absent, citrus-fruit growing proved to be profitable on the Pacific coast. Later importations of trees resulted in the introduction of this pest, which increased in a few years at so enormous a rate that the whole industry was threatened in large areas. Finally entomologists suggested that the pest be studied in its native land, to see what kept it in check there. Its enemy was found to be one of the “lady-bird” beetle. These beetles were introduced into this country, sometimes aided by artificial hatching in incubators, and set free in the infested territory. In a few years after the beetles were introduced, the cottony cushion scale was almost eradicated and the citrus-fruit industry became again profitable. Fortunately the beetle did not in turn become a pest as has happened in other instances where one species has been imported to check another.

It appears that man always has to pay a penalty in settling a country. He often brings with him species or varieties never before found there, and eradicates partially or entirely native

plants and animals; thus he upsets the balance so intricately adjusted over a long period. For this reason chiefly, sprays of various kinds must be used by fruit growers, since the natural enemies of the various insect pests have been interfered with and often almost if not entirely destroyed. Whenever we upset the balance in nature resulting from centuries of adjustment, we are almost sure to have trouble.

The question is continually asked, "Does this law of natural selection, resulting from the struggle for existence and the survival of the fittest, apply to mankind? Is man on the same basis as other animals and plants? Is not this a doctrine that teaches war instead of peace?"

The answer is a seeming contradiction: it can be stated, so far as the past is concerned, in both the affirmative and the negative. It is quite true that many individuals have started quarrels with a weaker foe just because they were able to conquer them and thus show their physical superiority. However, the tendency for the survival of the strongest physically is lessening each generation. Only a thousand years ago, fighting power and physical supremacy were usually the deciding factors, but not very often to-day. Mental power, except in the lowest tribes, has replaced physical strength as the final test of fitness.

In the animal and plant world, we have found that at best only two out of a multitude of seeds or a litter of young can survive out in the wild. Is this small proportion of success what we want in modern human society?

Of course the answer is No, although one sometimes finds individuals even to-day who believe that they were born to rule and others to slave. The majority of us, however, in democratic states, do not believe in this doctrine. Stated biologically, nearly all of us in democracies still believe, must necessarily believe, in the survival of the fittest, since we certainly do not wish to become a weaker species; but we do not believe that only one or two children out of a group, tribe, city, or country are fit to survive. We believe that all children should be made fit to survive, through proper physical, mental, and moral education.

We believe that it is the chief function of the state to make all the children of all the people fit to survive. That is what all good schools are trying to accomplish. Since the public schools of America are playing so large a part in making children fit to survive—to really live—it is no wonder that public education for all the children is considered the very keystone of our civilization—the great hope for the future.

QUESTIONS

1. Can you suggest a reason why, prior to Darwin's time, no one could give a good explanation as to how evolution takes place?

2. Can you suggest a method by which animal and plant life could get necessary food unless there were an excess of offspring or seed produced by the parent animals and plants?

3. It is obvious that any species would soon fail if the weak survived and attempted to reproduce its species, but what would happen to the species if only the mediocre survived and reproduced, rather than either the weakest or the best?

4. Other than in man, do you think failure is the more frequent before reaching adult size or after reaching adult size?

5. Name a species of your region which illustrates a break in the "balance in nature."

6. What is happening in this region (where balance is broken) to some of the other species of plant and animal life?

7. Should man continue to break the balance in nature? Why or why not?

8. Would it ordinarily be better to use the term *development* instead of *evolution*? Why or why not?

9. Are there any facts and principles in this chapter that children in the elementary grades should know? In the junior high school? In the senior high school? Give reasons for your answers.

10. Is the phrase "survival of the best" essentially equivalent to "survival of the fittest"?

11. In what ways do competition and coöperation supplement each other?

CHAPTER VI

MAN'S METHOD OF SELECTION

The origin of domesticated and tamed species—How man creates new varieties of plants and animals—Burbank and other breeders—Do all nationalities and races of human beings belong to the same species?—Is man the result of natural or artificial selection?—Does domestication by man weaken or strengthen a species?

Artificial selection is in several ways very different from and in some ways much like natural selection. The chief difference is this: natural selection results in the survival of the fittest from the standpoint of benefit to the species concerned; artificial selection results in the survival of the animals and plants best suited to man's needs even though the animals and plants that thus survive might be very far from "fit" to survive under natural conditions. Under natural selection those individuals and species best fitted and best adapted to their environment, and thus able to compete successfully with other species and other individuals of their own species, survive; under artificial selection those best fitted and adapted to the needs of mankind survive, largely because they are protected by man from harmful competition.

The universal fact of variation is the foundation upon which both natural selection and artificial selection rest, and here perhaps is their greatest similarity. If the tendency to vary were not common to all domesticated and wild forms, the artificial selection of the finest, strongest, most beautiful, or most useful domesticated types would be equally as impossible as the operation of the law of the survival of the fittest among wild species would be under the same condition. In neither case could there be any selection. It appears, then, that variation is both a boon and a hindrance to the plant and animal breeder: while without

variation he could not produce new types, yet the tendency to vary makes it difficult to retain a new type once it has been found or produced.

Another difference between natural and artificial selection is that ordinarily only the healthiest and hardiest survive under the former process, while under the latter the weak often survive, if only they meet some need of mankind. Few varieties produced by artificial selection are able to hold their own if forced to compete with other varieties out in the wild. This is particularly true of chickens, and of the grain crops, such as wheat, oats, barley. In a very few years these types fail unless they are protected and selected year after year by man.

Artificial and natural selection also differ in the opportunity afforded for the survival of varying individuals. In the former, many varieties are produced and are caused to survive under the protecting care of man; in the latter, a new variation has small chance to survive out in nature since there is scant chance that a similar variation of the opposite sex will be found in the same vicinity at the same time. Even when this situation obtains, the chance of isolation for a long time, which will permit the new traits to become fixed, is very small. Man watches for variations and increases them if perchance they may serve him, whereas nature destroys them unless they are hardier, more prolific, or in some way serve the welfare of the species.

Artificial selection often is much more rapid than natural selection. Nature's chief way of succeeding is the trial-and-error method; thus thousands, even millions, of years are required to develop a desirable trait. Man might accomplish a similar thing in a few years by a very different method—the method first of deliberate selection and then of breeding toward a definite end and protecting the desirable stock of each generation. By careful selection and scientific breeding a new variety of wheat, hardier and larger, may be produced in a very few years, whereas nature would probably take thousands or hundreds of thousands of years to accomplish the same end.

It is also true that artificial selection causes many types of individuals and many traits to come into existence which under natural selection would never be produced except by the merest chance. Our highly developed dairy cattle and the egg-producing breeds of chickens would never have come into existence except by the hand of man. Such types as these are the result of long and careful selection, elimination of the undesirable, and protection and multiplication of the desirable.

In discussing this topic one is often asked if absolutely new traits are ever produced by artificial selection. The answer in final form is not yet formulated; it appears, however, that the only things that man does are (1) to develop the traits that a plant or animal already has by giving these traits a better chance, and (2) to combine two or more traits in such a way as to produce something which might possibly be called new.

It seems to be just as true of the human species as of other living things that the only characteristics that can be developed in a child or adult are those already in existence in a potential or undeveloped condition.

It is well known that all of our "tamed" varieties of animals and plants are modified wild forms. Most of these tamed species have been in existence almost as such for several thousand years and usually were selected out of a great group of related species or families. For example, the domesticated chicken is only one of over fourteen thousand species of birds, all laying eggs. Through long periods of time, from hundreds of species which may have been caged for egg-laying purposes, our ancestors selected the chicken as the best and most promising of the bird family to domesticate. With our present scientific knowledge concerning birds' food and behavior we can readily understand the selection and wonder why other birds were considered at all.

We would now readily discard for such purposes all the sparrows, finches, wrens, warblers, blackbirds, orioles, and a host of other small birds because their eggs are too small and too few in number; yet various peoples—we are told in story if

not in scientific records—selected these birds as egg producers. Owls and hawks would likewise be discarded because their food is meat and thus too hard for their captor to procure and preserve; yet owls and hawks have been tried as egg layers by various tribes. The eagle also would be eliminated because of its sharp claws, its few eggs, and its lack of docility. After surveying the whole class of birds, one is forced to admit that apparently only the *Gallinæ* order had the characteristics that would permit of its development into an egg-laying animal. Of all this order, the chicken, a pheasant from India, proved to be the very best. Its food can be stored in large quantities without spoiling, it is large enough, it is docile, but above all else it has a natural tendency to produce a larger number of eggs, even in the wild state, than almost any other type of bird life. Very naturally it has survived the culling process. In improving the chicken, man has only given these innate tendencies a better chance to develop.

In a similar way was the present dairy animal selected. Hundreds of animals have been used as milk producers, including the mare, the sheep, the zebra, the buffalo, the goat, and the cow. In some primitive tribes, species other than the goat and cow, are still used but are by no means so satisfactory as the cow. After thousands of trials, the cow was selected as the animal best fitted for milk production, with the goat coming second. This is now readily understood when one considers the cow's size, docility, food habits, and natural capacity to produce milk, even when wild—especially the last factor. A good milk animal is so important that a high degree of civilization is found only where large quantities of milk can be procured. Some authorities attribute the backwardness of the two Americas before the time of European settlement in part to the fact that there were no good milk animals prior to the introduction of cows and goats.

These two illustrations but typify the methods of all selection of animals and plants by man. Thousands of errors were doubtless made and thousands of individuals sacrificed in learning

which species were best fitted to contribute to the material needs of man, such as food, clothing, and shelter, or to his æsthetic needs or to his need for companionship.

Man is the only animal that has the power to select desirable natural traits in plants and animals and by giving them a better chance to allow these traits to develop. More recently man has attempted to produce new traits by combining two or more old traits—for instance, crossing large sour cherries with small sweet cherries, thus developing both large sweet and small sour types. Of course, the latter would be destroyed or cast aside. This type of scientific breeding, however, has had its rise since the rediscovery of Mendel's law in 1900. In a later chapter on Mendel's law this subject will be discussed in greater detail.

Unless one is attempting to produce new varieties by Mendelian crosses, the usual rule is to have in mind the desired type or standard and then select for protection and breeding those individuals that have most nearly attained that standard. For example, if one wished to produce an extremely large variety of Rhode Island Red poultry, the largest hens and roosters would be selected as breeders and from these the largest eggs, generation after generation, would be selected for incubation. In a few years the average size of the flock would be considerably increased. Sunflowers with large heads can be and have been produced by selecting the largest heads and the largest seeds in the heads, generation after generation. The same is true of large Shasta daisies and of many other plants.

Since there is an inborn tendency for everything to vary—in the tame as well as in the wild forms—and since some people like white chickens best, others black, and still others red, buff, or speckled, and since some like rose combs better than single, large size better than small, fighting types better than the docile, white eggs rather than brown eggs, we now have more than two hundred standard and recognized varieties of chickens.

Because pigeons of different colors, sizes, and shapes are desired, we have several score varieties of this, the *Columbæ* order of birds. Since some people like large horses best, others small

or medium in size; since some prefer black, red, pinto, we now have several dozen varieties and breeds of *Equus caballus*. In much the same way man has produced a number of varieties of sheep, pigs, goats, dogs, cats, geraniums, carnations, and what not.

Although the ancients were doubtless very crude in the matter of selection, using mostly the trial-and-error method, they were in the end decidedly successful in choosing the best species to "tame" for their own use. All of the important food plants and animals, save the turkey, corn, and potatoes, were in use in Europe, Asia, and Africa thousands of years ago. The three products just named will be recognized as the sole contribution of the two Americas to the important world foods. Had they been present in Europe, Asia, or Africa, they would doubtless have been selected by the natives as important foods. Since the discovery of America, they have spread to practically all parts of the world in which they can live.

One is often asked if there are several distinct species of human beings on earth or if all belong to the same species—and if they all belong to the same species, why and how such great variation.

The answer to the first part of the question is that there is now living only one species of human being, although at least two other species were once in existence. To be sure there are several definite and widely separated varieties of mankind, but even though very different in size, color, culture, and customs, all or nearly all of them do or can readily cross and produce fertile offspring. It is thought by many that a species includes all the individuals and varieties in a group that can successfully interbreed. This is probably the best definition of a species; if so, then there is only one living species of human beings.

Undoubtedly the chief reasons for several distinct varieties of human beings are, first, natural barriers, and secondly, race or nationality consciousness. We know that rabbits, chipmunks, squirrels, and other animals have developed several varieties because barriers have enforced isolation and allowed extreme varia-

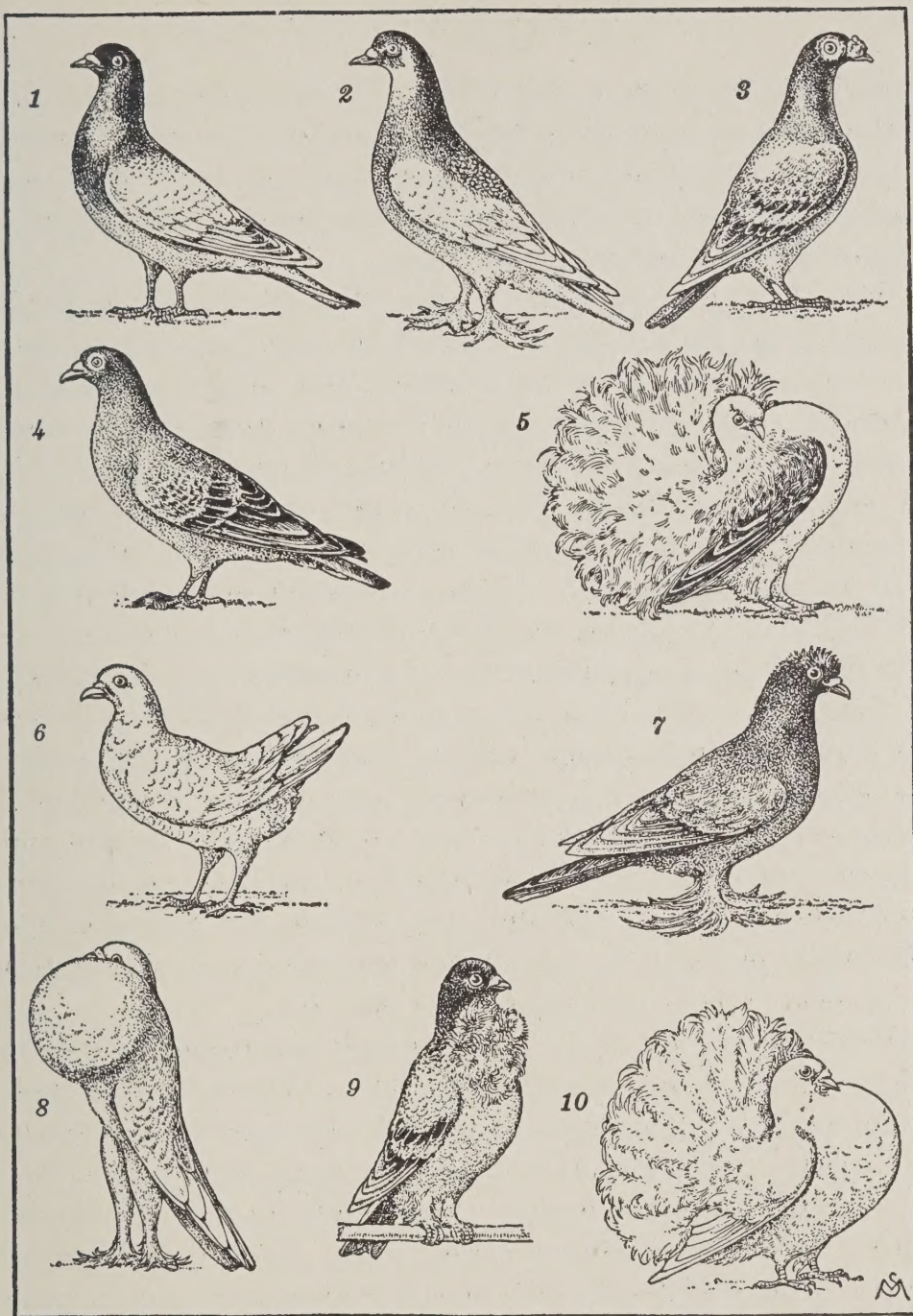


FIG. 7.—*Varieties of cultivated pigeons.* All these varieties and many others have been developed in recent times from the same stock or ancestry. A knowledge of heredity enables the fancier to obtain new combinations of characters in a few generations. 1, Silver Runt; 2, Muffed Tumbler; 3, Dagoon; 4, Homer; 5, Saddle Fan-Tail; 6, White Maltese; 7, English Red Trumpeter; 8, White Pouter; 9, English Owl; 10, White Fan-Tail. (From Gruenberg's *Biology and Human Life*, by permission of Ginn and Company, publishers.)

tions to start, continue, and develop. In the same way geographical separation or isolation has kept human types from blending. Even varieties of the human species that are not shut off from one another, may be kept from blending however by race or nationality consciousness or prejudice.

Man is in some ways the most variable of all animal species, due partly to an unintentional isolation in many regions for many centuries or even thousands of years, and partly to race or nationality consciousness enforced by strict tribal marriage customs or, in civilized societies, by laws. Even to-day there exist in many lands marriage laws which prevent intermarriage with foreigners; thus certain races have been kept relatively pure.

If we examine carefully this great variation in the human race, we find that part of it is due to widely different inheritance, and part to culture and training. It is maintained by some students of this problem that there is a greater difference between the lowest types of human beings and the highest types than between the highest types of the anthropoid apes and the lowest human being. Whether this be true or not, one is certainly safe in making this statement: there is an enormous gap between the lowest and highest types of mankind, so great that it is probably more difficult to describe the human species with any degree of accuracy than to describe any other living form.

Variation in color in the human family is extreme,—from the white of pure albinos to almost jet black. Variation in size is also wide, not taking into account the extreme variations (“freaks” or “sports”), either large or small. The range is from an average of scarcely four feet in height in some tribes to six feet in others, with corresponding differences in weight. Mentally there seems to be a greater difference than morphologically, ranging from the plane of the mental giant to that of the feeble-minded—a plane above which certain entire tribes scarcely rise. It is probable that the latter might improve greatly with the right kind of education, but it is safe to predict that there will always be a great gap between the average mental efforts of these low tribes and the average mental ability of the white and yellow races.

The question arises, "Can improvement in species continue indefinitely, particularly in the human species?" It is obvious that only a partial answer can be given, since no one can be certain that all the means which might result in the improvement of any species have been exhausted. We do have, however, a few well-established facts concerning this problem, particularly in regard to forms that are produced by fission or those that are the descendants of one self-fertilized individual.

Up to a few years ago it was thought that there was no limit to the capacity for improvement of any given species, but the fundamental researches of such men as Professor H. S. Jennings and Professor Gary N. Calkins have shown that this conclusion is not correct, at least as regards one factor—size. Professor Jennings, working with a common protozoan, *Paramecium caudatum*, found that normally there is considerable variation in size in this species, as is true in almost any species. Upon measurement of single individuals of *Paramecium*, he found that they varied in size and that the offspring resulting from binary fission also varied in size; but by selecting for hundreds of generations, he could not get them larger or smaller respectively than the largest or smallest individuals that he found in nature. In other words, although a small paramecium tended to produce offspring averaging somewhat smaller than the offspring of larger paramecia, he could not get individuals below a certain size, even though the attempt was made throughout hundreds of generations; nor could he get individuals larger than a certain size after an equally large number of trials. Stated in another way, descendants of one paramecium cannot be modified in size beyond a certain fixed point.

All the descendants of one individual, not the result of cross fertilization, are called *pure lines*, and their power to vary has been found to be exceedingly limited. Here the experimental biologist has been unable, thus far at least, to improve upon the extent of the variation, either upward or downward.

As to the possibility of continued improvement of species where there are two sexes, one can only speculate and draw what seems to be a reasonable conclusion.

Although mankind has tamed and used many kinds of animals and plants for thousands of years and although selection has been going on all of the time, yet this selection has been, for the most part, haphazard or unconscious or at best has rested upon very unsecure and unscientific foundations. Very little of a scientific nature was done to improve species before the year of the rediscovery of Mendel's work, 1900. Indeed, plant and animal breeders like Burbank often had very little scientific information upon which to base their work, relying rather upon the chance appearance of a favorable variant sometimes produced through simple crosses. To-day, however, hundreds of plant and animal breeders the world over are using more exact methods made available by science.

Perhaps not fewer than two hundred distinct varieties of animals and plants are now scientifically produced each year, and the number is becoming greater in proportion to the increase in the number of well-trained men who have an adequate understanding of the laws governing inheritance. New types of berries, flowers, potatoes, grasses, fruits, cattle, and chickens are appearing almost yearly, and the number of varieties is increasing rapidly. In the chapter on Mendel's Law of Inheritance the methods used for the production of new types will be given in some detail.

Has the end been reached in the improvement of any domesticated species that man has made a serious attempt to change? It has been estimated that the wild cow of the Texas plains produced in the neighborhood of seventy-seven pounds of butter-fat a year, probably just enough to raise one calf. This is approximately the amount produced by most wild cows. Under selective breeding, domestication, and the care of man, the butter-fat production has so improved decade after decade that now we have a number of cows producing more than a thousand pounds of butter-fat a year, nearly fifteen times as much as that of the wild animal. At this writing the accepted record for butter-fat production for one year is over eleven hundred pounds. Accompanying this butter-fat are more than

twenty thousand pounds of milk—more than ten tons—or about twenty times the weight of the average cow.

Even though there has been this remarkable increase in production of butter-fat, no informed dairyman is willing to say that the end has been reached or even closely approximated.

In the improvement of our domesticated chickens we have an equally astounding record. The wild jungle fowl of India, is the principal progenitor of our domesticated varieties. This species in its wild state lays from twelve to fifteen eggs each year, just enough to keep its kind in existence; yet under man's care large poultry flocks average yearly ten times this number for each hen, with some individuals producing fifteen times as many and a few over twenty times as many. The accepted yearly record of egg-production for a single hen is apparently 348 eggs. Nor has the improvement been in egg production only; in some varieties there has been a significant increase in size also. The end of improvement in poultry is not yet in sight.

Improvement in swine has also been marked, as anyone visiting a good country fair may observe. Individual hogs weighing approximately a thousand pounds are frequently seen. What a great contrast to the wild boar producing little fat and weighing only about one hundred pounds! The improvement in sheep is hardly less noteworthy although not so easy to observe. The quantity and quality of wool have undergone marked improvement, as one may learn if one traces the history of the wool market. In fact, nearly every animal of the farm is the result of a series of improvements of its particular variety.

Nor is the great improvement limited to animals: plants also have made equally impressive records. Although the ancestry of many cultivated plants is obscure, yet the origins of some are well known.

The common Indian corn, *Zea mays*, has developed from a very small ear, almost a "nubbin," with separate kernels, to the large, full ears found in many a cornfield. Probably the ancestral corn would not have produced over ten bushels to the acre, whereas a yield of over one hundred bushels to the acre

is at present not uncommon. Wheat, oats, barley, and nearly all other grains show a similar record of improvement due to man's selection and care. Cultivated fruits and flowers have also undergone marvelous changes, and no evidence indicates that the ultimate forms have yet been reached or even approached.

The enormous increase in butter-fat production in cows, in egg production in chickens, in wool production in sheep, in fat and meat production in hogs, in the yield of corn, oats, wheat, barley, is due to the fact that on the whole we have let the best survive and have given the offspring of a chosen few a better chance to develop their innate traits. If we take the typical dairy cow as an example, we find that the descendants of a relatively few individuals now populate our dairies. No longer need the dairy cow spend her energy using her horns to fight away wolves and similar animals, nor need she use much of her fat in winter to keep warm, nor spend much muscular energy grazing over large areas to find enough of the right kind of food. Animal foes have been killed off or fenced out, warm stables are provided, and plenty of nourishing food is supplied; thus the cow may concentrate on milk production.

Similarly chickens, swine, sheep, corn, and wheat are given a better chance by man to develop their innate tendencies. Man lessens the rigor of the battle formerly fought with other species and with other forces such as cold, drought, and scanty food supply. The power to do this with the animals and the plants he desires to use is one evidence of man's partial domination of nature.

It is clear, then, that artificial selection and natural selection are built on the same foundation—namely, variation on the one hand, and the tendency to remain constant on the other. Out in the wild we found that there must be an excess of production of seed or offspring merely to insure the permanence of the species. Under domestication there must also be an excess of production; otherwise the farmer or rancher would have no crop to sell on the market. Sometimes man attempts to increase

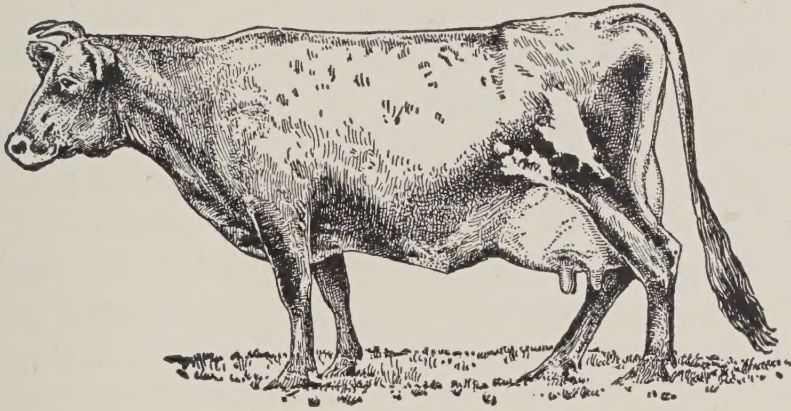


FIG. 8.—Improved varieties of domesticated animals. The contrast between the modern high-bred Jersey and the ancient banting, or between the high-bred Russian wolfhound and an ordinary yellow dog, is typical of the changes brought about in the course of many generations by the steady work of selecting the most desirable kinds of individuals to be the parents of the following generation. (From Gruenberg's *Biology and Human Life*, by permission of Ginn and Company, publishers.)

the quantity of the crop and sometimes the quality, but usually both.

Ranching, farming, fruit growing, are thus very largely a matter of increasing the excess in nature, both quantitatively and qualitatively, so that there will be something to dispose of when the crop is mature or so that the quality of the product may insure its sale. Man usually follows the lead of nature except where new varieties are created by deliberate crossing of



FIG. 9.—Improvement in Geranium: at left, the original wild form and at right the latest improved form. (From *Evolution and Animal Life*, by Jordan and Kellogg, after photographs by Burbank. By permission of the publishers, D. Appleton and Company, New York.)

varieties, and gives the favorable individuals and traits a better chance, reaping a reward in proportion as he is successful.

The question naturally follows, will man himself continue to improve generation after generation? The answer seems to be that he may, although he is not so likely to do so

without effort on his own part. The human being as a species is inclined to be more careful of the health of the animals and plants that he breeds than he is of himself. He is inclined to pay little attention to his own breeding and much attention to appeasing his whims, desires, and instincts regardless of consequences to the next generation. That many races and nationalities have entirely disappeared from the face of the earth is well known in history and that others will follow is highly probable. That there has been a general increase in the culture or the civilization of mankind considered as a whole, it is safe to assume.

General improvement in the future may depend largely upon the effort that we make to put into practice the known facts and laws of heredity. The details of the facts and principles that should be adopted will be dealt with in a later chapter, *The Improvement of the Human Species* (Chapter XXIII).

It seems entirely safe to say that where there is only one parent, as in reproduction by fission or by self-fertilization, improvement of the species can go on but little; but that where there are two sexes concerned in the reproduction of the individual, improvement, at least theoretically, is unlimited. The evolution of two separate sexes in higher forms, while the lower forms have only one sex or both sexes in the same individual, is perhaps partially explained here. In two sexes there is always a chance for a recombination of the characters of the parents in the offspring in a new way; if there is only one sex, or if the individual is self-fertilized, recombination is impossible.

The tools for scientific work in the field of heredity have been in man's hands for only a short quarter of a century, but even in this time great progress has been made. It is reasonable to suppose that in the field of artificial selection, as in almost any other branch of science, the great majority of discoveries are still to be made. Many new and unheard-of varieties will doubtless come into existence at the hand of man. Some may be larger, some more prolific, some more beautiful, and some more speedy.

There is a vital difference between the old method of artificial selection and the new: the former rested its method of improvement largely on the chance of finding favorable individuals which were given a chance to develop; the latter more and more is deciding in advance what is wanted and then setting to work to attain this end, guided by the well-founded facts and principles of heredity. Man's biological improvement will depend very largely upon his willingness to submit to those laws already well known and to those yet to be discovered.

If we attempt to apply the facts and laws of artificial selection

directly to the problem of the teacher, we may say that one of his chief duties is to find out what the innate tendencies, abilities, and capacities of the pupils are and to give these dormant or poorly developed traits a better chance to develop by means of better teaching, better books, wider acquaintance, more information, and wise encouragement. The teacher has no chance to develop new traits in the child as he might do with some animals and plants by selection and breeding; hence he must apply his entire energy to giving the potentialities of each child a better chance to develop by giving him the best environment possible.

QUESTIONS

1. Name some trait or characteristic not yet developed in an animal or plant by man that you think could be developed for the benefit of mankind.
2. Do you think it possible that the several races of mankind now on earth will ever become so different that successful mating will be impossible—that there will be no children from interracial marriages because the parents will be too different from each other to reproduce successfully?
3. Do you think a Hottentot or a Bushman, by means of a fine environment, could be raised to the level of the average Caucasian? What evidence do you have in support of your belief or disbelief?
4. Why is it probably true that no hen will ever be developed that can lay a dozen eggs a day?
5. Why is it undesirable to have cobless corn or seedless watermelons?
6. What traits or characters native to children have been developed only to a very small extent or not at all? Of these, are there some which it would be possible and profitable to develop through education?
7. Which, if any, of the facts of this chapter are suitable for teaching purposes in the elementary school? Is it always wise to teach all the facts concerning a subject that a child is capable of comprehending? Give reasons for your answer.

CHAPTER VII

ADAPTATION

How adaptation to environment is usually brought about—Degrees of adaptation—What usually happens to highly specialized animals?—Human adaptations—To what degree does man, more particularly the child, adapt himself to his environment?—Adaptability of children as compared with adults.

One often uses certain words and phrases very glibly, thinking to explain certain phenomena, whereas the phenomenon in question may thereby be made more inexplicable. We say that "it is second nature" for a man to act in a certain way and assume that we have explained his actions, while what we have actually done is to admit that we are too ignorant of the factors involved to understand why he acted as he did.

Likewise we often say that this plant or that animal or that human being is well adapted to the place it or he occupies in nature. What is meant by adaptation? On what does it rest? Do plants and animals adapt themselves or does only the favorable variant in any given species survive and in turn produce offspring that eventually occupy the land because naturally able to meet the environmental conditions imposed? Are living things perfectly adapted to the places where they are now living? Can some animals adapt themselves better than others? Does man adapt himself in a different way than do the lower animals?

No one can give a final answer to all of these questions, and no single person knows all of the facts that have been found by a multitude of painstaking investigations; but there are certain facts fairly well agreed upon by most biologists.

Adaptation, like natural selection and artificial selection, is built upon the universal fact of variation in all species. If all the individuals of any species were identical, it would mean that

the species was perfectly fixed, and of course further adaptation would be out of the question. Even if a permanently fixed species were perfectly adapted, it would be only a matter of time until that species would be not so well adapted because of the changing environment.

Whether during their individual lifetimes plants and animals actually adapt themselves to a given environment or whether only the favorable variant survives, is a disputed question very much akin to the question of the inheritance of acquired characters by succeeding generations.

If we say that an animal is well adapted to its environment, we mean that it can live in a designated locality with comparative ease, able to cope with the climatic conditions, able to compete with the other animals and plants as an individual, and able successfully to reproduce its kind generation after generation. Seldom are adaptations showy factors, easily picked out and demonstrated to the unthinking; rather they are prosaic factors, so common that they must be searched for and carefully identified. The common everyday things in nearly every field of life are seldom seen and more seldom understood.

Adaptation is usually a matter of a few major and a great number of minor factors. For convenience these factors can be divided into (1) those pertaining to the animal or plant, and (2) those pertaining to the environment. Number one includes such major factors as the ability to get food, the ability to reproduce, the ability to endure climatic conditions, and the ability to compete successfully with other species in a given area. Number two includes such factors as wind, temperature, latitude, altitude, humidity, and pressure, all of which, in a sense, might be thought of as subdivisions of the several major factors, yet strictly environmental in nature. Doubtless there are many unknown factors which help to determine whether this or that animal or plant can survive in any given area. Research workers uncover more and more factors every decade and doubtless will continue to do so.

Although we shall learn in our study of geographical distribu-

tion that many plants and animals are not to be found where they could live successfully, it is probably equally true that all species have attempted to enter many areas where they have been unsuccessful. Even though we grant, for the moment, that species do adapt themselves in the long course of ages to a new area or to decidedly changed conditions in the old area, nearly all will agree that, out in the wild, visible modifications of structure or function in one or a few generations are seldom to be seen.

What we usually find, if we search carefully for the facts, is that the species, if it becomes modified on entering a new area, is largely the progeny of certain members of the species present all the while but in much smaller numbers. The new environment, it seems, weeds out more and more of the individuals of that species which may have been successful in the old environment, but are unsuccessful in the new. If the individuals that were adapted to the old environment are few in number in the new surroundings, and if those that were few in number in the old environment become greater in number in the new surroundings, it follows automatically that the new area will soon have a population composed largely of the descendants of those adapted to the new area. Those adapted to the old environment may never pass entirely out of existence; they may persist but in relatively as small a proportion as was represented by the new adaptations in the old environment.

Let us take a typical case. A certain plant found in the relatively low Allegheny Mountains is transplanted to the higher Rocky Mountains. One should keep in mind that few peaks of the Allegheny Mountains are as high as five thousand feet, whereas the plateau from which the peaks of the Rockies rise will average five thousand feet or more in altitude. In Colorado and surrounding states the elevation of the plains region often exceeds five thousand feet before even the foothills are reached.

We shall assume that the plant transplanted from the Alleghenies is able to meet the new conditions successfully except in the matter of altitude, which means a lower average temper-

ature. Not only does the plant now live successfully after several decades in the Rocky Mountains at an altitude equal to the highest points in the Alleghenies, but it is actually climbing the Rockies. Each decade it is found higher up the mountain sides than in the preceding decade, and there is no reason to assume that it has yet reached its maximum altitude. It has now attained ten thousand feet in altitude. How can this adaptation to a higher altitude be explained except by the assumption that the plant has adapted itself to its new environment?

A number of factors enter, but let us examine one carefully. In its native habitat we find that this plant varies in all of its parts, as is to be expected, including the amount of "fuzz" or "hair" on its stems and leaves. About five per cent of the plants in the favorable (native) area grow "fuzz" so scanty that it is barely visible, almost glabrous; about twenty per cent have a little more, but still not an abundance; about fifty per cent have an average amount; about twenty per cent, a large amount; while about five per cent are exceedingly heavily covered with this hair-like exterior. It seems safe to assume that this "fuzz" or "hair" is a protection to plants against the cold, and against rapid changes in weather—the function of true hair on animals.

In its native habitat in the Allegheny Mountains, it would seem safe to say that those in the fifty per cent group were probably better adapted than those in the other groups and that the two groups with only five per cent each were not nearly so well adapted even as those in the twenty per cent groups. On transference to the Rocky Mountains we find at 6,000 feet altitude that the five per cent group with almost no fuzz is barely represented, the twenty per cent group with "fuzz" rather thin is hardly holding its own, as is also the case with the fifty per cent group. The twenty per cent group, however, with a large amount of "fuzz" has increased in percentage somewhat, while the five per cent group, with the exceedingly heavy covering of "fuzz," has greatly increased in percentage.

In each succeeding thousand feet in altitude we find the heavily hirsute plants increasing in percentage and those with a light

amount of hair correspondingly decreasing. At an altitude of ten thousand feet almost none but the heavily fuzzed plants are to be found. Why? The answer, it seems, is that only those with a heavy coat of "hair" have been able to live and reproduce at the altitude of ten thousand feet; consequently, their seed has occupied the land. Those not adapted have failed to live and consequently have failed to reproduce. Since like tends to beget like, instead of the exceedingly fuzzy individuals being represented by only a meager five per cent as in their original habitat, they

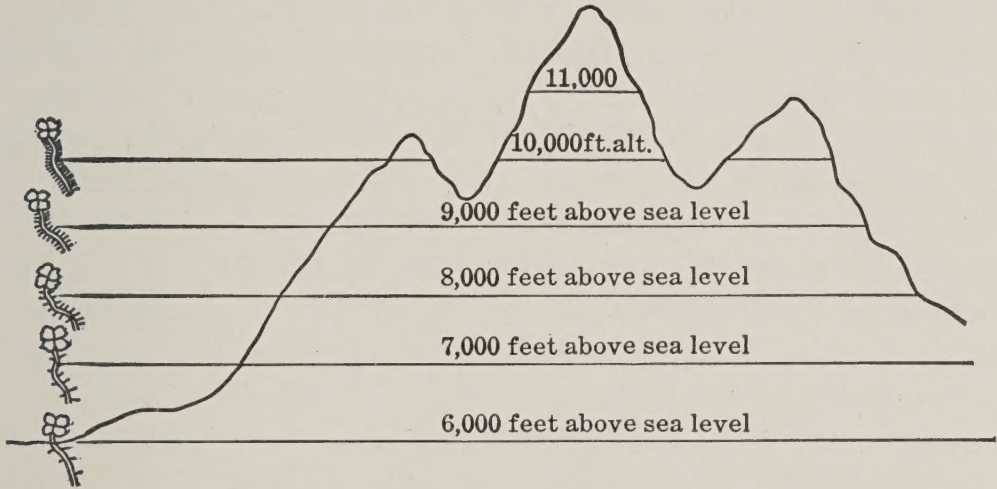


FIG. 10.—Diagrammatic drawing of a plant species "adapting" itself to higher and higher elevations in the mountains by means of an increasing amount of "hair" or "fuzz" on stems and leaves.

have now increased to nearly one hundred per cent at an altitude of ten thousand feet.

This illustration, typical of what has happened thousands of times, probably explains what always happens when a plant "adapts itself." To put it in a more nearly correct form, we may conclude that the plants did not adapt themselves to any noticeable degree¹ but that only those plants survived that were al-

¹ It should be added that the heavily fuzzed plants sometimes give rise to a few thinly fuzzed ones and the thinly fuzzed plants occasionally to the heavily "fuzzed" ones, following the well-known law of regression. This law is treated in a later chapter dealing with Inheritance. Although the above does happen in a small percentage of individuals, yet, by and large, the law still holds of like *tending* to reproduce like. In the high mountains at 10,000 feet elevation the thinly "fuzzed" offspring of the heavily fuzzed plants would of course fail to

ready adapted; those that were the favorable variants so far as the temperature at an altitude of 10,000 feet elevation is concerned.

Another illustration—this time not imaginary but coming under the observation of the writer. At Gunnison, Colorado, there was introduced from the Eastern states over forty years ago a particular variety of raspberry bush. Most of the original plants failed, but a few survived and from these few have come a large number of raspberry bushes well adapted to live in the vicinity of Gunnison. It should be kept in mind that the place from which the original plants came has an altitude of about five hundred feet with the temperature seldom much below zero in winter. The humidity is relatively high as is also the temperature in summer. The Gunnison area is decidedly different; it has an altitude of seven thousand seven hundred feet; the temperature may go to thirty degrees below zero any winter for a few nights; the humidity is very low nearly all the time; and the temperature is not high even in summer. There is evidently a great contrast in climatic conditions. Now what happened in this process of adaptation to the Gunnison area? In all probability the surviving raspberry bushes did not actually adapt themselves to any great extent; rather the few favorable variations (individuals) were already somewhat adapted, they survived, and from these few have come all those now found in the Gunnison area.

In the case of man the situation is somewhat similar, although doubtless the human species has the power of adaptation, and does adapt itself to varying conditions much better and more rapidly than any other species. It is an observed fact, however, that the Negro races are better adapted—thrive and survive better—in the warm climates than elsewhere and that the white race thrives better in cooler climates. The latter seems to be particularly true of the lighter varieties of the white race,

survive and reproduce and it would naturally follow at this elevation that there could be no heavily fuzzed plants coming from thinly fuzzed ones, since the latter do not come to maturity and reproduce at this altitude.

especially the Nordics.¹ Now it is well known that Negroes live far up in the temperate zone and that some Nordics are to be found in the torrid zone, but that either is successful in the other's environment would be upheld by few. Indeed, the handicaps of the white race in attempting to live in the tropics have been clearly demonstrated. Each variety seems to be well adapted in its native habitat, and this adaptation probably has been due more to the elimination of the unfit than to the changing of the type to meet the environment.

New varieties and new species of life are able to live in a new environment only if adapted, at least a little more than fifty per cent, to their environment. Whether the method of adaptation be change within the individual or merely the survival of the favorable variant for that particular region, is a question that need not be settled here. Of one thing we can be sure—if any species cannot meet the conditions of life in a given area, it fails, as has been the case with perhaps five times as many species as are now living on the earth.

It seems that adaptation, whatever be the process, is a continuous thing and that, whenever the percentage of inadaptability exceeds the percentage of adaptability, then extinction for the individual or the species is the result. Doubtless some species are just barely fitted to live in a given area and are poor examples of the species when compared to the best. The large Douglas Fir tree seems to be about at its best in the area of the state of Washington, where it grows rapidly and to a large size, often exceeding five feet in diameter and much above a hundred feet in height. Contrast this with the scrubby specimens of the same species, equally old, gnarled, and bent, that we may find at timber line, around eleven thousand five hundred feet, in the Colorado Rockies.

The degree of adaptability is an interesting study. Some species seem to be able to live only within a very narrow range of latitude while other species are widely spread. Banana trees

¹ The tall, long-headed, light-haired, blue-eyed people found most frequently among the Scandinavians, Scotch, and Anglo-Saxons.

cannot live where there is a frost. Corals of certain species are to be found only at a very limited depth, where the temperature never goes below a certain rather high level and is nearly constant. The common dandelion, on the other hand, thrives both in the regions where there is heavy freezing and in those where there is none. *Since man has the most highly developed brain and is also one of the most variable of all species, it is only natural that he should be found to be the most adaptable.* Because of his highly developed brain, he can adapt himself to a marked degree by increasing or decreasing the amount of clothing worn, by increasing the amount of humidity in a room through evaporation of water, by increasing the circulation of air by means of electric fans thus making the air feel cooler, by bringing in food from a distance, by imitating, if desired, spring and summer all the year round, and in various other ways. These adaptations are made possible because man can learn from experience and because the lessons so learned can be improved and taught to each succeeding generation.

The great difference in adaptability exhibited by the human being in contrast with all other forms of life can scarcely be stressed too much. In the human being we have an *intelligent adaptation—a genuine learning from experience*—which is likely to be remembered and passed on to succeeding generations. This ability to learn quickly from an experience, often only once repeated, and to profit by it, is distinctly a human trait. Other forms of life may learn from experience by the trial-and-error method or their adaptation may be improved by the much slower process of natural variation and natural selection, evident almost everywhere in both the animal and plant realms; but man's chief prerogative is that he may make new adaptations readily and teach them to his offspring.

Quick adaptation of a very genuine sort is decidedly evident and *is the basis of the learning process. Our entire educational theory is based upon the fact that children and adults can and do learn from experience and profit individually thereby.* Plants and the lower animals in a way may be said to learn from experience when

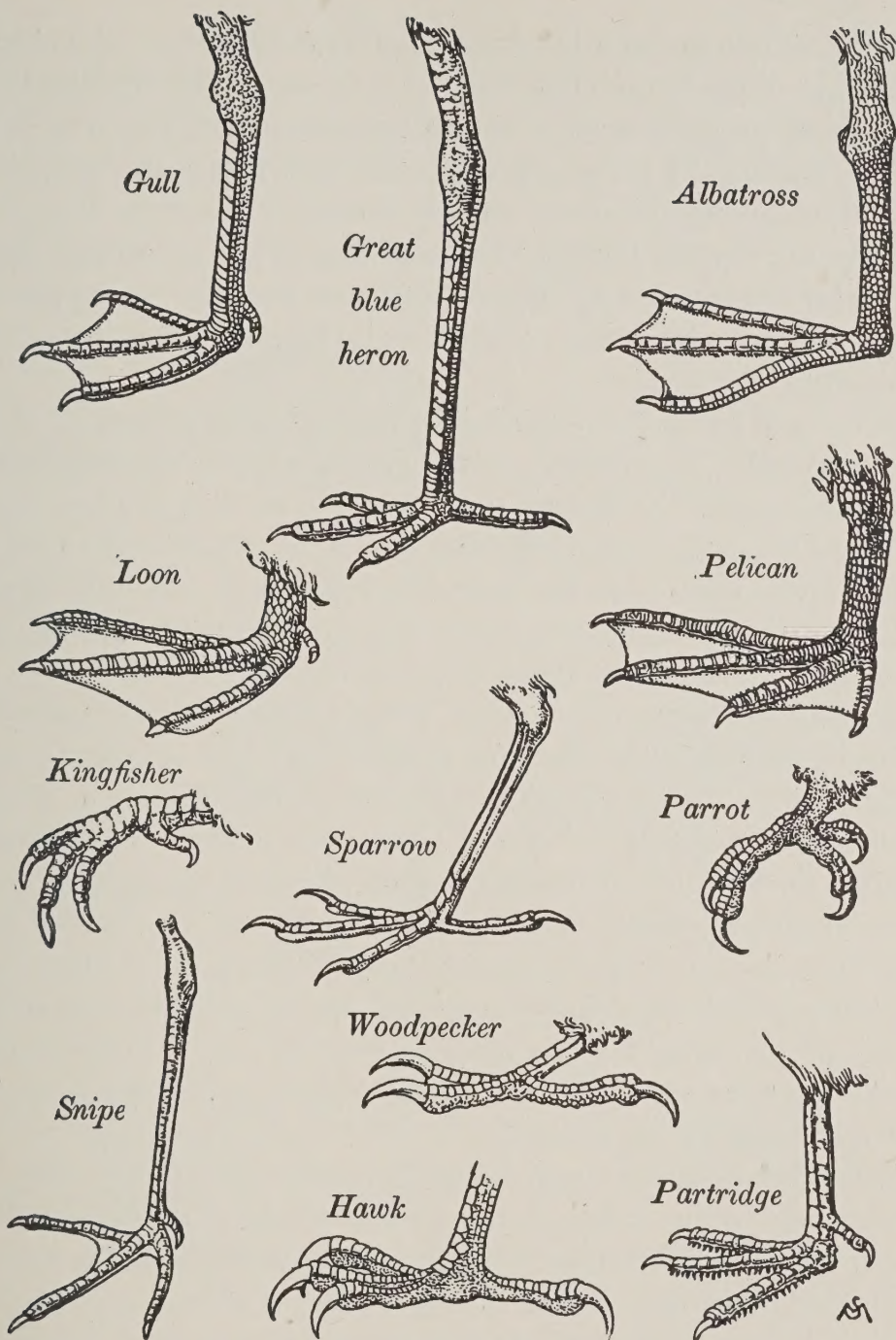


FIG. 11.—*Specialization in the legs of birds.* Although the legs of birds are constructed on the same general plan, there are many distinctive features that correspond to the different habits of life. (From Gruenberg's *Biology and Human Life*, by permission of Ginn and Company, publishers.)

this is extended over a long period of time, but this "learning" is not at all like human learning. It is accomplished by the elimination of the great majority and the survival of only the few, who acquired the favorable traits through fortunate variation and who unwittingly pass on the favorable traits to the next generation. In the human race each and every individual may profit by the experience himself, and may transfer it to succeeding generations by actual example or by language or other forms of communication.

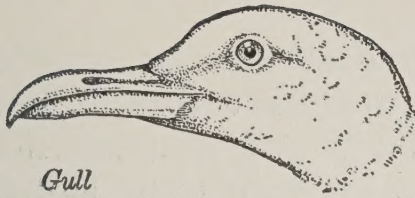
Intelligent adaptation exhibited by human beings is the basis of all improvement in civilization, which of course includes educational theory and practice. In fact the growth of civilization has been the gradual accumulation of improved adaptations or learnings. What civilization is to the race, education is to the individual. Without intelligent adaptation on the part of the great majority of human beings there could be no civilization.

Among the many hundreds of adaptations of plants and animals there are some that are spectacular, and appeal to our imagination. Perhaps none is more wonderful than that of the white-tailed ptarmigan ¹ of the Rocky Mountains. In the winter it is pure white, matching the snow; while in the summer it is grayish brown, closely resembling the rocks and branches of the surrounding region; in the spring and fall it is partially white and partially gray-brown closely approaching the normal color of its surroundings, whether the snow be melting leaving some of the ground bare or whether the snowfall be not heavy enough as yet entirely to cover the ground.

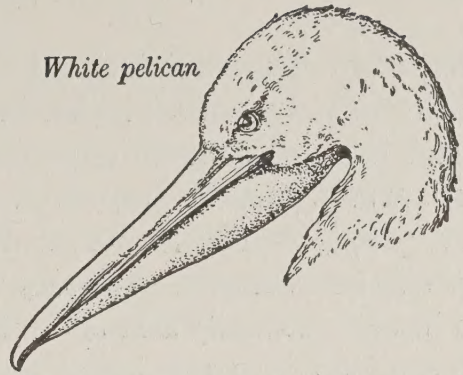
The long beak of most humming birds shows a wonderful adaptation to the long tubular corolla of the flowers upon the nectar of which they feed. One humming bird which the writer measured had a total length of nine inches, of which the beak was four and three fourths inches and the rest of the body, including the tail, only four and one fourth inches.

The extremely large claws of the badger, enabling it to dig holes rapidly in order to secure as food other smaller animals

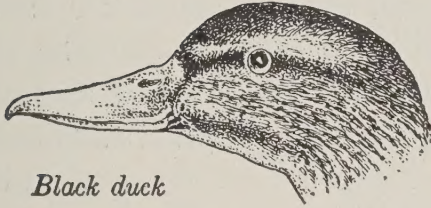
¹ *Lagopus leucurus*.



Gull



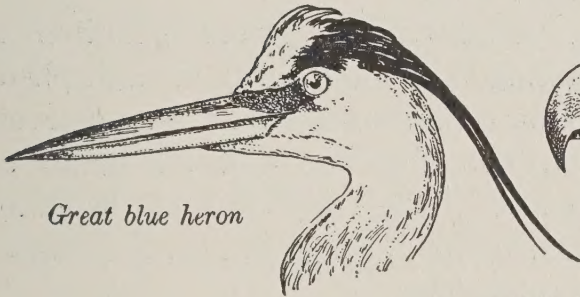
White pelican



Black duck



Flamingo



Great blue heron



Bald eagle



Paroquet



American crossbill

FIG. 12.—*Specialization in the beaks of birds.* A beak is a beak, but the bill of a sparrow is different from that of a stork. Many of the distinctive features found in the beaks of different species of birds correspond to specialized ways of getting food or to the character of the food eaten. (From Gruenberg's *Biology and Human Life*, by permission of Ginn and Company, publishers.)

that burrow, are outstanding as a special adaptation as are also the extremely powerful, shortened, front legs of the mole, which make it possible for the animal to dig and push itself through the soil. The Venus fly-trap, so famous in botany texts, illustrates a very special adaptation on the part of a plant, enabling this species to secure the necessary nitrogenous food-materials found in insects. Equally famous is the pitcher plant which catches its insect food in a specially prepared cup of water. The kangaroo is also an outstanding example of adaptation. The enormous hind legs enable it to make very rapid progress by a series of successive leaps. It also possesses what is practically a third leg in the form of a large tail, upon which it can rest and brace itself. The powerful tail is also a help in leaping. The heavy, sharp talon of the eagle illustrates a very specialized organ for catching and holding prey, as does also its beak which is used for tearing the flesh of its prey from the bones.

The number of highly specialized adaptations exhibited in both the plant and animal kingdoms could easily be multiplied. Many seemingly simple adaptations are seen to be truly marvelous when carefully studied. The more one studies a family of animals or plants, the more keenly is one impressed by the many specific adaptations for securing food, competing with enemies, and withstanding climatic conditions.

Adaptation in the human family is shown in two different ways, (1) biological, and (2) intellectual or mental. Under the first heading come such special adaptations as the upright position, the nimble fingers, the adjustment of the eyes to binocular vision, the development of the organs of articulate speech, and the enlarged cranium housing the enlarged cerebrum. The significance of the upright position can scarcely be overstressed, since such a posture releases the front limbs so that they can be used as hands. This freeing of the hands for "prehensile" use has made man preëminently the "tool-using" animal. It takes but little reflection to get some notion of what this has meant to human progress.

Under the second heading come the products of the special

ability to think, to reason, to show human intelligence. *The trait of intelligence is man's greatest biological adaptation*—the basis of almost all other adaptations distinctly human in nature. *This special function is more than equal in significance to man's development than all the other adaptations in nature combined.* The most remarkable thing about this trait is that the intelligent adaptations which it makes possible can be *socially inherited*, thus benefiting each succeeding generation. The rise and growth of the capacity to pass on to each generation some of the experience accumulated by its predecessors has been the most remarkable development in the evolution of human life.

QUESTIONS

1. Do you think that man adapts himself better to his environment than any and all other species? Compare with birds, fishes, mammals, insects.
2. What evidence do you have in support of such a belief?
3. Do you think that children are, on the average, able more quickly to adapt themselves to a new environment and to strange people than adults?
4. Do generalized animals and plants or highly specialized animals and plants adapt themselves the more readily to a new environment?
5. Is it ever possible for a plant or an animal to become too perfectly adapted to its environment? If so, illustrate.
6. What happens to individuals and to species that fail to adapt themselves to a changing environment?
7. Is adaptation to school life a rather natural or an artificial thing? Why?
8. Can you name ways in which adults adapt themselves to a new environment more quickly and better than children? If so, what enables them to do it?
9. How and in what manner would it profit children to learn some of the facts concerning adaptation?

CHAPTER VIII

ISOLATION AND GEOGRAPHICAL DISTRIBUTION

Why all species of plant and animal life are not found where they can best live—The effect of isolation on plants, on animals, and on man—Why remote oceanic island species often differ greatly from continental species—Various kinds of barriers—Jordan's law—Isolation as an aid to species formation—Isolation as the chief cause of the many races and nationalities of human beings—The effect of isolation on children.

Numerous animals and plants not native or indigenous to regions where they now thrive, sometimes survive better than do the native fauna or flora. Occasionally, indeed, the newcomers brought in by man succeed so well that some of the indigenous plants or animals are reduced to a fraction of their former abundance, if not completely driven out of existence. For example, no one questions the success of the English sparrow in America or of the rabbit in Australia; yet both were introduced by man in comparatively recent years. A number of species once existing in a wild form in America are entirely absent now, while some of the same species are represented on other continents by direct descendants. Such is true of the horse, the camel, and other less well-known forms.

Why were (and are) many animals and plants not to be found where we know they could thrive as well as those that are native? Why were the horse and the camel originally found in America, and why were they entirely absent for a long time,—indeed until the Spaniards brought them to our shores in the beginning of the sixteenth century? Why is man the most widespread of all species?

These questions vexed scientists for many years, but now an answer is available, at least in part. Not until the advent of the

idea of evolution was it possible to understand the riddle, because surely if plants and animals were created just as they now are, they would have been placed in the localities where they could thrive best and survive.

With the background of evolution we now know that there are at least three good reasons why all animals and plants are not found in every region that could support them:

1. They have been unable to get to every locality because of barriers such as oceans, mountains, deserts, and wide rivers.
2. They may have been in a given locality originally but were unable to adapt themselves—to change as fast as the environment—and have failed, possibly only in this locality.
3. They may have been present originally but have changed and adapted themselves to meet the ever-changing environment and have become new species.

Let us examine each of these possibilities in order.

There are many examples of the first, but perhaps none could be better than the introduction of rabbits into Australia or the importation of English sparrows into America, from England and the continent. (See Chapter V.) In Australia, the rabbit is such a pest that much of the grass and herbage which should go for the grazing of sheep and cattle is consumed by the rabbits. It is estimated that two hundred rabbits eat at least as much as one cow. There are millions of rabbits; consequently, there is less food for the cattle. The English sparrow has rapidly displaced much more attractive birds in America. There seems to be not a single characteristic to recommend this bird, since it is not beautiful, does not have a beautiful song,—in fact has no interesting traits. Lacking the enemies found in their native lands, the rabbits and the English sparrow have flourished. These enemies are not imported for fear they might become worse than the original pest, as has been the case several times where such a remedy has been tried.

The reason why trout were not originally in some streams above certain falls or in isolated lakes is easily understood since there were no means, before men took a hand in the procedure,

by which they could get there. Many species of trout, and thousands of other species of fish as well, can live and thrive where they were not originally found.

It is maintained that there are no American wolves on any continent other than America, not even on the northeastern corner of northern Asia where only Bering Strait separates the two continents. That the American wolf could live in Siberia and the Siberian wolf in North America there cannot be the slightest doubt, since climatic and food conditions in certain areas on both continents are almost identical.

Reindeer were not found on the North American continent until introduced recently by man. They are now successfully bred in Alaska. The latest statistics list 350,000 reindeer, but it was only twenty-five years ago that the first herd of 1280 was imported from Siberia. Of course, the only reason why the reindeer and the American wolf were not found on the American and Asiatic continents respectively, is that they could not get there. The former was desirable and was introduced with success; the latter is undesirable and probably never will be transported to Siberian shores.

It is just as true that there are plants found elsewhere that could thrive in America and plants native to America that could thrive in many other parts of the world. Of the grain crops only Indian corn is native to America. Wheat, oats, barley, rye, and other grains are successfully grown in America, however, and Indian corn in other countries. Potatoes are native to America but are successfully grown now in many countries of the world. Not only are domesticated plants in great number now grown successfully in many places other than in their native land but wild forms are often successful away from home.

So far the illustrations have served to exemplify the first of the reasons stated above. We shall next take up reason number two,—namely, that many animals and plants once lived in regions where they are no longer found. These were unable to meet the conditions of these regions and failed, leaving only their fossil skeletons or other remains to prove that they were

once there. It would be difficult to find better examples than the horse and the camel.

In western United States abundant fossil remains have been found representing the horse in its earlier stages of evolution, even when it was less than twenty inches tall and had four distinct toes, with but a remnant of the fifth, on each front foot. The skeletons are so widely distributed and abundant that it is safe to say that for long periods of time, several million years ago, the horse was one of the dominant mammals of our continent. Here is an animal that failed to adjust itself rapidly enough to changing conditions and went the way of hundreds of thousands of other species. The camel at one time was abundant in North America, as proved by fossil remains, but it, too, failed, leaving no descendants.

On a number of occasions the nightingale has been introduced into the United States, because of its beautiful song, but in a few months no trace could be found of the species. For some reason it could not meet the conditions of our environment.

The third reason given why every species is not represented in every region is that upon reaching the new territory it adapts itself to the new environment, and continuing to do so through long periods of time, eventually becomes a different species. If, as well as the living forms, one studies carefully the fossil remains of any group of animals such as chipmunks, rabbits, squirrels, or snails, one sees clearly that the ancestral form is no longer present. It has been replaced by a number of more or less different species, all sufficiently alike however to be placed in the same genus or family. In studying a group like the chipmunks of California or the jackrabbits of southwestern United States, one is struck by the fact that each species differs a little or a great deal, as the case may be, from the others, each doubtless fitting its own environment better than if it had remained like the ancestral form. If each species of chipmunk or jackrabbit had not changed to meet or keep pace with the changing environment, there would be no representatives of these groups of animals in these regions.

If one studies the topography of the earth, using a contour map, or better yet if one travels extensively, one is impressed with the wide variations in the surface features of the earth. If one goes to a large museum and studies the animals and plants found there, one is also forcibly struck with the great variation in species. One might naturally suppose that there is some connection between these two facts—and there certainly is.

It is a fundamental hypothesis of biology that animals and plants that cannot adjust themselves to a particular environment must move to a new environment or cease to exist. It follows that, in the process of adjustment, if animals and plants are to inhabit every region, there must be differences, often great differences, in species even within the same family.

There are a number of factors that make for great differences in the environment of plants and animals. Altitude and latitude make for differences in temperature, and sometimes in moisture. There are also variations in pressure both in the air and in the water. Rainfall is one of the most widely varying factors. The depth of the soil is also variable, ranging from a fraction of an inch (or none) to several hundred feet in some favored areas. Temperature is a fourth large factor, so variable from the tropics to the poles that the mere mention of these terms is sufficient to bring forth vivid pictures of the extreme variations that exist. Pressure at different depths of the ocean and of deep lakes is decidedly variable, so much so that few forms of life are found to exist outside of certain rather limited horizontal ranges, simply because they are unable to meet widely varying pressures.

These five main factors, together with many minor ones, and the fact that there are many associating plants and animals to be reckoned with in almost any region, automatically make it necessary that there be many species, often widely different from their closest relatives elsewhere. It is practically safe to say that one is likely to find at least as many different species of animals and plant life as there are distinctly different environments.

Migratory animals, such as birds, and plants that are readily

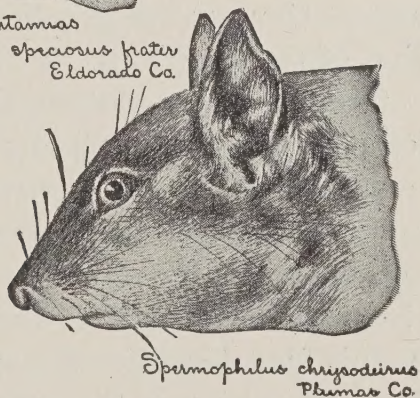
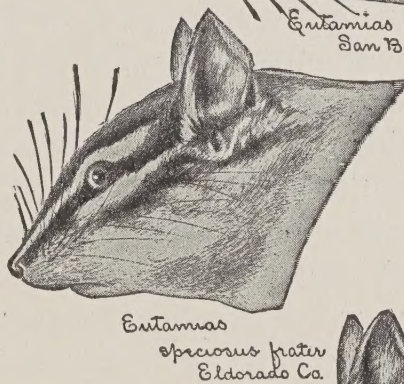
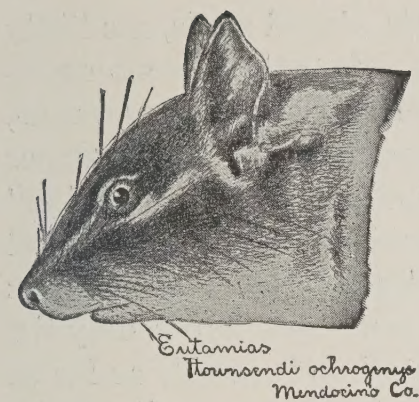


FIG. 13.—Some chipmunks of California, showing distinct species produced through isolation. (From *Evolution and Animal Life*, by Jordan and Kellogg, after William Sackton Atkinson. By permission of the publishers, D. Appleton and Company, New York.)

distributed, such as cat-tails with their winged seeds, are likely to change much more slowly than forms of life that are more confined to a given area, such as fresh-water snails, snakes, beans, and wheat. One can agree with the statement of Dr. E. Coues that "Migration holds species true: localization lets them slip." If a pair of animals or a plant seed finds its way to a new and quite different locality, one of two things is likely to happen: first, if the species is able to meet the conditions imposed by the new environment, it reproduces its kind and spreads as far as possible; and second, the particular and perhaps peculiar traits of these, the first parents, will probably be continued in the offspring and perhaps accentuated, since there are no others of its kind to unite with to form different traits,—there is no chance for a trait to lose itself in the multitude by crossing. In the course of long periods of time continuous adjustment doubtless brings about new species, as is easily proved if one studies the flora and fauna of the islands of the sea or the remains of plants and animals that existed in the past.

Islands close to the mainland have a climate almost identical with that of the mainland, and the life on island and mainland is usually found to be almost identical. The farther out from the mainland, the more surely will the climate be different, and in almost the same degree the more surely will the life differ from that of the mainland.

Geographical isolation, then, is very much like artificial selection, except that the former may have been operating for a much longer period. And here we come to a very important point, namely, *natural selection is not enough to account for new species*, since unless isolated, any small or even fairly large variation would probably be lost in the herd by inbreeding. Because of this fact doubtless thousands of minute traits are kept from becoming those of the entire species. When complete isolation takes place, there is no competition, and any trait is allowed a chance to persist and develop.

It is probable, therefore, that new species can be formed in only two ways, *by very great variations which the biologist calls "mu-*

tations," and by natural selection plus isolation for long periods of time. The latter is easily comprehended and is probably the way in which most new species have been formed. New varieties of a species may be produced by Mendelian crosses and cross breeding almost at will, but not new species.

A certain law (often called Jordan's law from its author, David Starr Jordan) states in compact form a generalization concerning the probability of finding related species in a given locality: "Given any species in any region, the nearest related species is not likely to be found in the same region nor in a remote region, but in a neighboring district separated from the first by a barrier of some sort, or at least by a belt of country the breadth of which gives the effect of a barrier."

One is likely to find few exceptions to this law, and these few can usually be explained. It is easy to see that closely related species would hardly be found in the same region because the individuals with varying traits would not get a chance to continue the variation but would become lost in the herd. Closely related species in regions remote from each other would also be almost impossible because of the number of barriers that would have to be crossed. That closely related species might be found in neighboring regions is a reasonable assumption because once in a long time there might be an opportunity for species to cross the barrier and enter the territory close by. The proximity of the two regions would also suggest a somewhat similar environment which would call for similar but not exactly the same adaptations on the part of the species concerned.

Occasionally two closely related species are found in the same region, but these have probably been formed by mutation or else the barrier existing during the formation of the two species has been broken down. It is a phenomenon which might result, for instance, after long periods of the wearing down of mountains.

Attempts have been made to divide the land and water areas of life into divisions called realms, in order to demonstrate the great variation in climatic conditions and to illustrate why spe-

cies of the same family may be so different. The classification that follows is but one of many that might be made; but it seems to the writer to be a logical one.

The ocean may be divided into three great divisions so far as fish are concerned, called littoral, pelagic, and bassalian. Most other forms of sea life would fall into these three groups also.

(a) The *littoral* or shore group is composed of those marine animals living close to the shore in water of moderate depth. These animals never venture far into the open sea either at the surface or in the depths.

(b) The *pelagic* realm occupies the open sea down to a moderate depth. In this realm are often to be found schools of fish or great areas of protozoa or plankton,—minute forms of life upon which many of the fishes feed. The types found here seldom come near the shore and are unable to go to great depths because of the pressure.

(c) The *bassalian* realm is the realm of great depths, usually stated as from 2,500 to 25,000 feet. Here the pressure is enormous, sometimes over five tons to the square inch. Because of great pressure, complete darkness, and extreme cold, almost no life is found in this realm.

Of course, one might divide the ocean into isotherm realms, using some definite range of temperature for each realm. Regardless of the divisions made, one would find that even in the ocean, where it might appear that any or all species would be found anywhere in the “seven seas,” there are fairly definite “life zones,” and that each form stays within a comparatively restricted area. Different species of whales are found in rather well-defined and limited waters because of the factors of food supply, pressure, and temperature.

The realms of the land are harder to determine because many more important factors are involved. Suffice it to say that they have been divided into Arctic, North Temperate, South American, Indo-African, Patagonian, Lemurian, Australian.¹ Other

¹ The classification of realms is taken from Jordan, D. S., and Kellogg, V. E., *Evolution and Animal Life*. D. Appleton and Co., 1907

divisions equally good, perhaps, have also been made. All of these correspond closely to the common conceptions of the geography of the earth. Only the terms Patagonian and Lemurian need be explained. The former includes the south temperate zone of South America and the latter the large island of Madagascar, lying off the east coast of Africa.

In each of these realms are to be found species of animal and plant life not found in the others, unless introduced there by man. There are a few species such as the mallard duck and some grebes which are found in several of these areas, but only one species is found in all—man.

Now why is it that man is more widely distributed than any other form of life? The answer is that man, as we have seen, (Chapter VII) is the most adaptable of all animals, first because he is highly variable, and secondly because he has the advantage of a highly developed brain which gives him the capacity for intelligent adaptation,—learning or profiting by experience.

However, in spite of man's capacity to adapt himself to almost any climate and to migrate much as he chooses from place to place, tribes and races have stayed to a remarkable degree in limited areas, so much so that very distinct races and nationalities have arisen. Some groups have been isolated for so long a time that they have become fairly well fixed in size, color, and stature. Some seem to be on the road to the formation of distinct species, and possibly such a thing would result if it were possible for their isolation to be continued long enough.

That the Caucasian race is quite different in a number of ways from the Mongols is evident on the surface. That the Negro is different from the Caucasian and the Mongol is equally plain. If migration and transportation had always been as easy as at present, it is highly probable that we should not have such divergent races and nationalities as now exist.

Not only do peoples naturally differ widely from each other if long separated, but there grows up within the tribe or race the desire to be different from all others and the desire to develop a distinct nationality. Each is inclined to believe his group a

little better than the rest and scorns association with the world outside. Severe penalties have been inflicted, should anyone presume to go outside of his realm or to mix with the foreigner, as in Japan for several hundred years before Japan adopted Western civilization. Thus the accumulation of traditions has reinforced the factor of isolation in continuing and perhaps intensifying racial differences.

With the coming of improved transportation and a greater dependence of one part of the earth upon the others for food, clothing, shelter, medicine, and luxuries, this aloofness and sense of superiority is bound to be minimized, for science is showing that the general *levels* of *native* ability in the civilized races are not widely different and that the variation in native intelligence among the members of a race are much wider than the variations among the levels of intelligence (or the average intelligence) of different races.

Isolation of a part of the people in one nation is often accompanied by a corresponding difference in manners, ideas, and customs. One widely traveled in the United States usually has little difficulty in telling whether a person is native to the South, the West, or the East.

Isolation was so complete among the American Indians before the white man's appearance that scores of tribes with different dialects, customs, and ideas existed—so different that because of these different customs and ideas they often warred among themselves as much as against the white man. Indeed the existence of the many different languages and dialects of the world is due almost entirely to geographical isolation. Without natural or racial barriers two dialects side by side would have little opportunity of distinct survival. They would tend to fuse. Good examples of natural national barriers are the English Channel, the Pyrenees Mountains, and the Sahara Desert.

The fact that isolation is the main cause for differences among human races, and the fact that easy transportation is rapidly breaking down those former natural national barriers, lead one to ask whether the present races and nationalities will al-

ways remain distinct and different or whether they will tend to fuse.

We have fairly exact records of intermarriage on a large scale in ancient times between separate races where one conquered the other, or along the border where intermingling naturally takes place, and history seems to show that eventually fusion of the peoples inhabiting a given area generally takes place. There are few outstanding exceptions.

On the whole it is probable that the intermarriage of *widely different* races is a bad thing for both races concerned. The fall of many nations has been attributed by some to such intermixture, since the better stock seems generally to deteriorate on blending with the poorer. Be that as it may, there seem to be grave dangers both biological and sociological when race intermarriage is practiced.

The facts in this chapter have an important bearing upon educational problems. The variations among school children may be observed not only in their physical characteristics and in their intelligence but also in their customs and manners. The teacher who is aware that isolation more than anything else has brought about variations of the last-named type is bound to be more sympathetic and probably more intelligent in dealing with the problems to which they give rise than the teacher who believes that peculiarities in manners and standards of conduct are in some way bound up with unchangeable racial characteristics. It is especially important, too, for the teacher to know that alleged racial differences in intelligence are likely to be greatly exaggerated.

Biologically children vary widely in the amount of native ability that they inherit. This native ability, we seem, as teachers, to be unable to change but little, if at all. The only thing we can do is to give the best possible environment in order to bring out these native traits.

The social inheritance of the school children of America, however, is susceptible to control, since it is an external matter, not internal as is the case of biological inheritance. Although we find

all kinds of schools in our country, from the very good to the very poor, yet on the whole, most of them succeed in creating a national consciousness—a sense of oneness, akin in a social way to that which we find expressed biologically in animals of a given species that inhabit any given isolated area. The United States with its diverse national and racial origins and antecedents, is much more a nation socially than biologically. One of the important functions of elementary education in a large country is to unify the people through a common culture which will tend to correct the variations in standards that are likely to occur among groups which are isolated from one another either geographically (although this influence is not so important now as formerly), or by occupations, religions, and the like.

QUESTIONS

1. Biologically speaking do you think the people of the several geographical units of the United States (East, West, North, South) are becoming more alike or less alike? Why?
2. Considering the human race as a whole, do you think it has been a good thing for the majority of mankind that large groups and stocks have been physically separated from each other for long periods of time?
3. On the whole do you think it desirable or undesirable that widely different races, biologically speaking, such as the Mongolian and the Caucasian should intermarry? Why?
4. Can you think of any reason, other than biological, why individuals from widely different races should not marry?
5. If Jordan's law is valid, how is it possible that one sometimes finds two closely related species of chipmunks in the same region?
6. Do we want the people of the United States to have the same biological inheritance? The same social inheritance?
7. How nearly should we attempt to give to every child in the primary grades the same training? Give reasons for your answer.
8. Should the training be more diversified in the elementary grades or in the high school? In the high school or in the college? Why?
9. Make a list of the facts in this chapter that you were taught in the elementary school or in the high school. Would it have been possible for you, at that time, to understand the biological interpretation of these facts?

CHAPTER IX

COLOR AS EXPRESSED IN PLANTS, ANIMALS, AND MAN

Protective coloration—Aggressive protective coloration—Mimicry—Warning coloration—Sexual selection—Survival in spite of color—Color as a factor in the survival of human races and species—Does the Caucasian race dominate because it has white skin?

At the outset it should be said that there is no general agreement on the theories set forth in this chapter. There are even those who say, with some supporting facts, that the colors of plants and animals have little to do with the survival of species, and yet others who say there is no such thing as sexual selection. A conservative view is that color often does play a part in the life of the animal and that sexual selection is a fact, if the term is interpreted rightly, but that in both cases, theories have far outrun the substantiating facts.

It is probably safe to say that for the majority of animals color aids, at least a little, in the survival of the species; that for other animals color is a distinct handicap, *the species surviving in spite of its color, not because of it*; and that for still others color neither aids nor hampers.

In the case of the white-tailed ptarmigan, mentioned in the chapter on adaptation, it can hardly be reasonably maintained that the precise similarity in color to the surroundings is a mere matter of accident. It should be kept in mind that, in addition to the fall moulting characteristic of most birds, this species also moults in the spring even though its feathers are not worn out to any noticeable degree. So closely does the white-tailed ptarmigan match the surroundings in winter, spring, summer, and fall that it is often used as our best example of *protective coloration* (Theory No. 1).

The theory of protective coloration assumes that those species

which closely match their surroundings are not seen by their enemies, consequently are not destroyed, and thus are able to reproduce their kind in a given area. Conversely, then, those individuals of a species that do not match their surroundings very well are easily seen and consequently are likely to be destroyed, leaving no offspring. Thus, since like tends to beget like, any given region would soon be populated by the descendants of those that matched their surroundings closely and the competition would become keener year by year among those that survived, so that eventually the great majority of the individuals would closely simulate the color of their surroundings.

There are numerous examples of animals that are protectively colored. Most wild rabbits in America are grayish in color, often turning lighter in winter, thus matching their surroundings the year round. The caterpillars of many moths are green, resembling closely the leaves on which they feed. Some butterflies and moths are so nearly like their surroundings as to be seldom noticed unless perchance they move. A number of species of grasshoppers can scarcely be distinguished from their surroundings, matching so closely that a person may have to look for several minutes in a very small area before seeing one.

Not only do certain individuals in a given region closely resemble their surroundings but sometimes the majority of the species in the area are protectively colored. If one tabulates the animals that live out on the more arid plains of the West, one is struck with the fact that most of them are of a tawny gray or brownish gray color; one finds it difficult to see them unless they are moving. Prairie dogs are dusky brown in color, matching closely the grayish brown surroundings; ground squirrels are likewise of a tawny color; coyotes and rabbits are hard to see, unless moving, as are also badgers and antelopes. If coiled and still, the prairie rattlesnake is hidden from view because of its color. Many of the insects are also grayish brown. In fact it is difficult to name any native animal of the plains that has a color in sharp contrast to the surroundings, except the once

abundant bison and the skunk, the latter a night animal. The bison, because of its strength, speed, and fighting qualities was able, it seems, to survive in spite of its color. The color of the bison though is not so very dissimilar to those animals that are referred to as protected.

The animals of the North are likewise, although not always, protectively colored, having a tendency to be somewhat white. Good examples are the arctic fox, the white-tailed ptarmigan, and the snowy owl. The polar bear, also white, will be considered under another heading.

Those animals inhabiting the tropics, where vegetation grows luxuriantly, have a tendency to be highly colored, typified by parrots, paroquets, cockatoos, and macaws. On first thought it might appear that the highly colored birds would be very conspicuous, but those who have traveled and lived in the tropics assure us that they are not. On the contrary birds with somber color would stand out against their brilliant surroundings and would be very noticeable.

It seems that animals the world over often depend for their safety upon the fact that they are well concealed from their

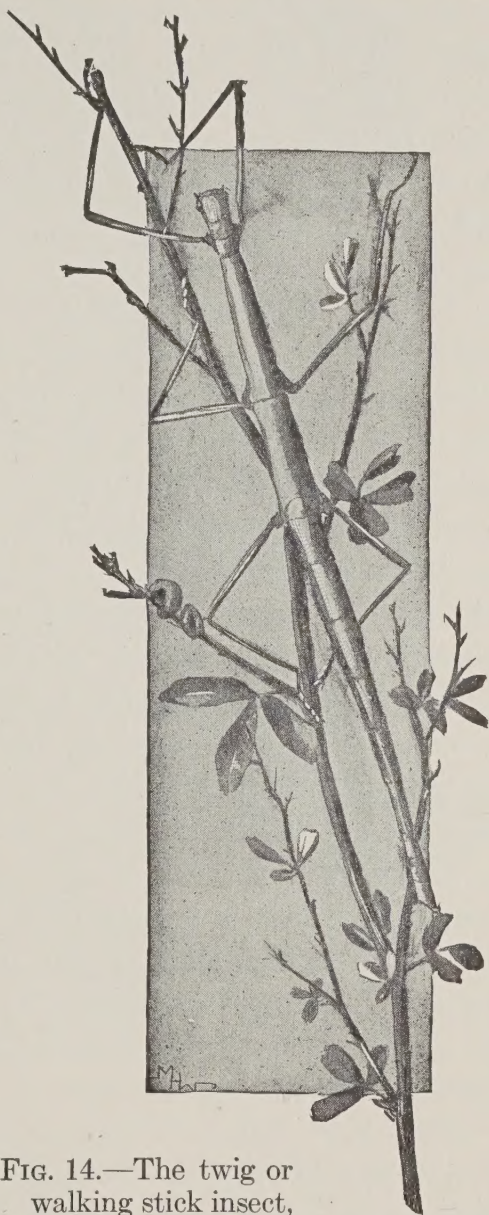


FIG. 14.—The twig or walking stick insect, *Diapheromera femorata*. (From Kellogg, *Elementary Zoölogy*, by permission of the publishers, Henry Holt and Company.)

enemies. Unconsciously most of the animals protectively colored seem to realize that they do harmonize with their surroundings, since ordinarily they will not budge an inch when their worst enemy is close by. On a number of occasions the writer has accidentally spied the outline of a well-protected bird or mammal and has tried to see how closely he could approach it, sometimes coming within a very few feet and occasionally within a few inches. This happened on several occasions in connection with rabbits and bob-whites.

In 1909 appeared a notable book by Thayer¹ dealing with protective coloration among animals. The author emphasized the fact that species which are protectively colored seldom have the same color all over: they are usually darker on top, lighter on the sides, and much lighter underneath. The explanation is that the direct white light striking the darker upper surface makes it appear lighter than it really is, while the indirect or shadow light striking the under surface makes it appear darker than it really is. Thus in color both the upper surface and the under surface resemble the sides of the animal which are between the two color extremes. Because of this combined effect the whole animal appears to be of one color—usually much like the surroundings.

If the animal were of one color all over, the upper surface would appear lighter than it really is, the side about as it is, and the under surface darker than it is. Such an animal would have contrasting colors, would be conspicuous, and naturally would be seized as food more often by its enemies than if it varied from dark above to light underneath.

This law, called "Thayer's Law" by many, can easily be tested in most regions. To be sure, a number of animals will be found not colored according to this law, but they are almost sure to have some other outstanding adaptation and hence survive in spite of their color, not because of it.

Another type of coloration found in animals is known as

¹ Thayer, G. H., *Concealing Coloration in the Animal Kingdom*. The Macmillan Company, 1909.

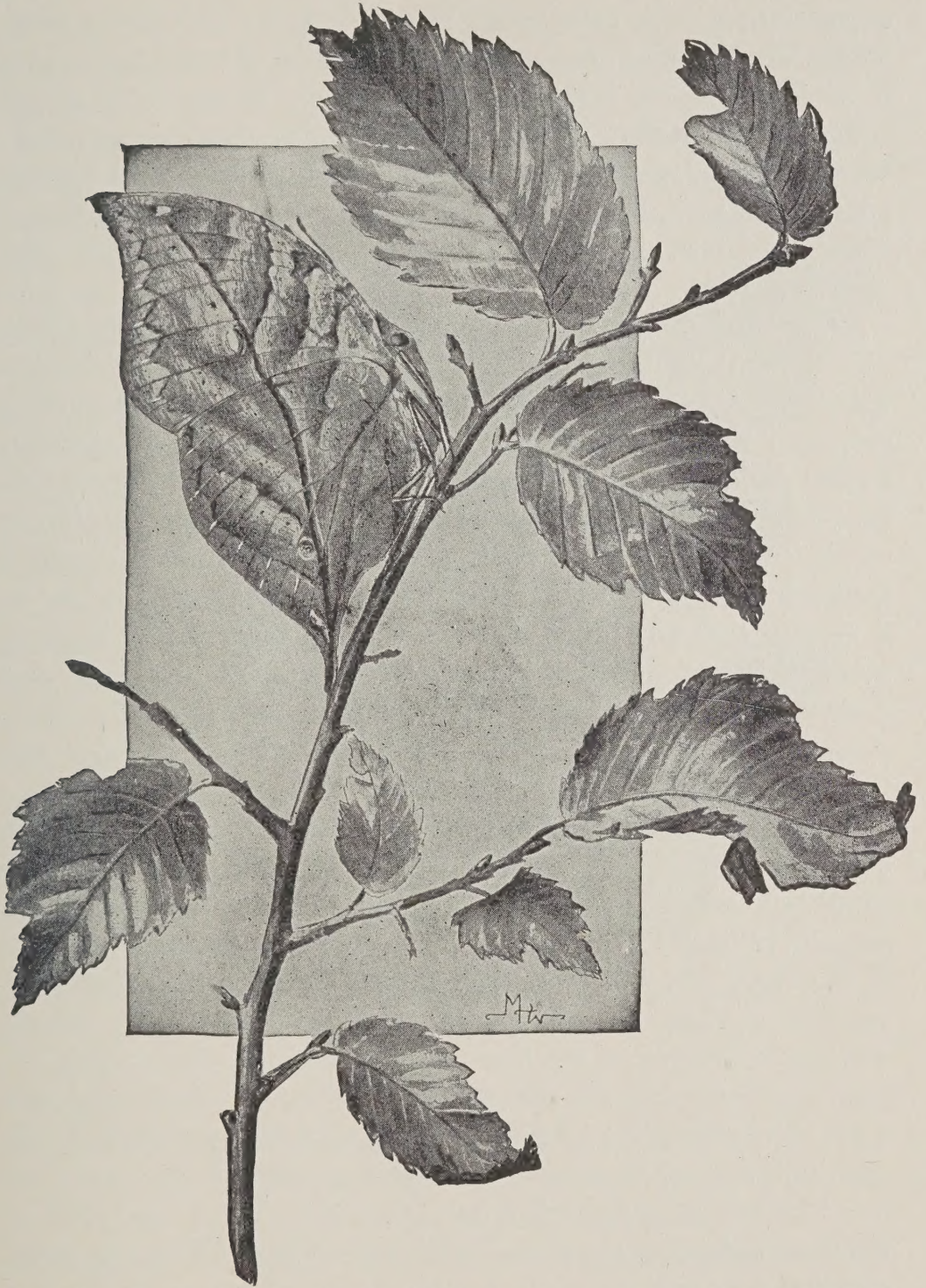


FIG. 15.—The dead-leaf butterfly, *Kallima* sp., a remarkable case of special protective resemblance. (From Kellogg.)

aggressive protective coloration (Theory No. 2). This differs from *protective coloration* only in the fact that the animals possessing it are the hunters instead of the hunted. These animals are colored much as are their surroundings so that they may get close to their prey before being seen. Good examples are the polar bear, the bobcat, the coyote, and the gray wolf. There are many other examples: one at least is almost sure to be found in any given locality.

Warning coloration (Theory No. 3) is also sometimes exhibited. It is thought by many that some animals with disagreeable protective attributes are conspicuously colored in order to be easily seen and thus avoided by other animals. The skunk and the weasel are outstanding examples. Now the skunk, by means of its special liquid scent bag, is able to protect itself against almost all enemies, and the theory is that if the other animals that might utilize it as food could only see it, they would leave it alone. It is certain that the broad white and black lines on the back of many skunks make them conspicuous night or day; thus the theory seems to have some justification in this case. Of course, it may turn out that another use for this conspicuous color will be found later.

The weasel has a long tail with a black tip, which it carries conspicuously elevated wherever it goes. Now the weasel is a small but ferocious animal seldom molested in its adult life by enemies because its bite is so vicious. Hawks and eagles attempting to carry the weasel in their talons are likely to suffer ugly wounds on legs and breast. Even dogs hesitate to attack weasels, so vicious is the bite made possible by their ability to turn and twist about in their skins. The weasel with its tail held up to the breezes like a flag seems to say, as do the skunk's black and white lines, "Come on and help yourself if you want to, but you will be better off if you leave me alone." As stated at the outset of the chapter, all of this is theory which remains to be definitely proved.

Mimicry is a fourth coloration theory often described. Its champions hold that some animals that are more or less helpless

and unprotected actually mimic the color of poisonous or dangerous relatives. Good examples are the bullsnake, several species of flies, and the viceroy butterfly.

An observer tramping in certain regions of the United States where both the bullsnake and the rattlesnake are common often mistakes the one for the other and, unless he investigates carefully, he may report seeing the poisonous rattler when actually it was the harmless bullsnake.

It should be kept in mind that the rattlesnake bite is very poisonous to all animals, large and small, including the human being, whereas the bullsnake has no fangs and consequently is not poisonous.

On careful in-



FIG. 16.—The monarch butterfly, *Anosia plexippus* (above), distasteful to birds, and the viceroy, *Basilarchia archippus* (below), which mimics it. (From Kellogg.)

vestigation the two snakes are found to be different. The poisonous variety has rattles on the tail whereas the non-poisonous has none. The specific color patterns on the two are different; yet when moving they appear to be somewhat alike.

When one finds that snakes are really very stupid animals and that the rattler seldom strikes to protect itself but uses its poisonous fangs chiefly to secure food, one is tempted to question the mimicry theory—at least in this case.

As stated, there are a number of flies which look on first glance to be members of the bee family. The theory is that the flies, having no stinger, changed their color to approximate the bees, which have a stinger, on the ground that birds leave the stinging bees alone. This all seems slightly reasonable, but when one learns that a number of birds use bees largely if not chiefly as food, one questions the survival value of such "mimicry."

Similarly the viceroy butterfly is found to resemble the distasteful monarch butterfly to a marked degree. This is particularly true of the majority of viceroys if found in the same region as the monarch. If the two are not found in the same region, it is maintained that only a small percentage of viceroys closely resemble the monarchs. This illustration seems to support the hypothesis better than the other two, but the similarity of the two species may possibly be explained in another way. The resemblance can be accounted for by the assumption that both species are adapted to the same environment, and thus logically could be much alike in color, rather than that one has "mimicked" the other. Mimicry implies intelligence; hence this theory is the more reasonably tenable.

The theory of *sexual selection* has aroused much discussion. In brief, those who uphold the theory advance the following evidence: (1) In a large number of species the color of the male bird is much more outstanding than that of the females and in the males themselves the degree of coloring differs greatly. Because of this difference the female birds are said to select for their mates the most attractively colored birds. (2) In the species of birds or mammals that sing or have calls of some kind, the females select the males with the most attractive calls or songs. (3) In some species of birds, mammals, and even insects, the males are said to go through a series of courting antics and the females apparently select as mates those that have the most attractive antics.

Those who vigorously uphold the theory of sexual selection will readily point out that males often are brilliantly colored, especially during the mating and nesting season, and that the

next generation, too, is highly colored; thus they argue that, as a rule, highly colored males were the male parents. They point out that warblers, orioles, house-finches, cardinals, and other birds sing very beautifully to their future mates during the pre-nesting season. They also say that anyone can observe the red-wing blackbird, the laysan albatross, and even some spiders going through an elaborate series of courting antics to attract the attention of the females. What, they ask, is all of this for—color, song, antics—unless it be to attract the females of their respective species for the purpose of being chosen as mates?

On first thought these statements appear to be the correct deductions from the facts observed. No one questions the fact of the variation in color, songs, and antics of males in many species, and some are particularly bright during the mating season, but variation here is also to be expected, since variation is universal in all life. It is the interpretation of the facts observed that is questioned, not the validity of the observations.

In the first place the theory, as given, seems untenable because it assumes far too much intelligence in selection on the part of the lower animals. Even in the human race, where choice is said to be the reason for marriage, there are many mistakes and outstanding errors. Little credit, in many cases, can be given to either sex for the choice made. It is reasonable to assume that lower species of animal life would have far less intelligence than man.

Now what are some of the facts against the theory? In the first place in nearly all of the species where outstanding coloring, beautiful song, or attractive antics are to be found, there are about as many males as females. One can fancy that a male bird, according to the theory of sexual selection, might say in his bird way, "Well, if I don't get you for a mate, there are plenty of others." And truly there would be; no male bird need lack a mate, since most birds are monogamous, and thus the next generation would be the offspring not of the brilliantly colored only, but of all manner of crosses, from the least to the most brilliant. Another argument against the theory of selection on the part of

the female is that in many cases—the rainbow trout, for instance—the male never sees the female that laid the eggs he fertilizes. The female may have deposited the eggs the day before and may be several miles away by the time of fertilization.

Again in many birds and mammals, generally supposed to represent the more intelligent species, there is no appreciable difference between the color of the male and female, the degree of variation being so slight that the human eye cannot readily detect it. For example, in crows, ravens, magpies, and jays, seldom does one find much variation in color. One cannot tell the male from the female. One never hears the remark: "There goes a particularly bright or highly colored male crow, pie, or jay." The above-named birds belong to one of the families of Aves, thought by many to be among the most intelligent of birds. The woodsman or the naturalist often reports observations to substantiate this statement. This family of birds would certainly make use of color variation in selecting mates if any group did.

It is equally true that the males of many of the most highly developed birds and mammals do not have an engaging song or call, some of them being almost mute. Certainly if a charming note or call would help in the preservation of the finest traits in the species, this would have evolved in the entire upper strata of bird and mammal life and not be found so scatteringly in the ranks, down to some of the lowest families.

The same general statement can be made for attractive antics. It is not the more highly evolved male birds and mammals that display these interesting movements; this habit of courting by bodily movements is found distributed throughout both classes—Aves and Mammalia—and even in the much lower insect class.

What, then, is the function of color, song, or antics if one refuses to believe in the selection of those males with the best display of color or talent? The writer will say frankly that he is unable to give a good answer, but it seems wiser to him to withhold judgment than to give a sentimental answer that has no adequate support. As to the peculiar antics of certain species

preceding the mating season, it is enough to say, perhaps, that health and great vigor on the part of the males might naturally lead to some form of physical expression, and that some sort of movement in connection with the premating season might be natural. The tremendous activity of the young male is noticeable in almost all species.

Likewise the beautiful song and call of certain birds and mammals probably represent only an exuberance of activity on the part of the male. That the song or call of the male is heard by the females of the species, no one denies, but that the female weighs all the evidence and then selects the one with the most beautiful note or call seems preposterous. *We* may find the calls pleasant to hear, but have we any evidence that the lower orders of animals find them pleasant? It is better to suspend judgment than to adopt a questionable explanation.

The color of male birds, however, seems to have a definite function, where the female bird has a somber color when compared to her mate. If one will observe carefully some of the male birds that are highly colored during the nesting season, such as orioles, red-wings, or yellow-headed blackbirds, one will find that they usually perch in rather conspicuous places. Often these birds are in the vicinity of the females on the nest, either in the tree tops, as in the case of orioles, or conspicuously on cat-tails or reeds, as in the case of blackbirds. If these highly colored males see any of their enemies, such as hawks, they do not scurry down among the branches of the trees or under the cat-tails or reeds; they fly off to some other tree or to a distant thicket, thus leaving the inconspicuous female with the eggs or young birds safe on the nest. If one keeps in mind the fact *that all life is so ordered that the next generation will be safe and successful*, it is reasonable to suppose that the brilliant colors of the male and the inconspicuous colors of the female have a survival value in contributing to the protection of the young and hence to preservation of the species. Even in the barnyard fowl and the turkey we find the more brilliant and strutting males far more conspicuous than the shy, more somber-colored females.

In addition to the fact that the males are often conspicuous and the females just the opposite, in order, possibly, to make sure of the next generation, we find that the young birds are very often colored so as not to be very noticeable, thus enhancing the chance of their growth to adulthood. Not only are the young often almost invisible in their natural habitat if not moving, because of their close resemblance to their environment, but also the eggs are often so decorated with speckles, spots, or streaks as to render them almost unnoticeable. Good examples of young and eggs thus protected are the nighthawk, the killdeer, and the Wilson's (Jack) snipe. Here we have, in some birds, four means by which color adds to the safety of the next generation—namely, inconspicuous eggs, inconspicuous young, inconspicuous females, and conspicuous males.

It should be kept in mind that in most birds and mammals, after the eggs have been fertilized, the males are no longer essential to the welfare of the young and to the next generation. To be sure it is usually highly desirable that the male be also alive to help gather food or direct the young to food, in case of precocial birds, or even to defend the young in some instances, but his contribution to the welfare of the young is nearly always small when compared with that of the female. Since an inherent tendency of all forms of life is to keep their kind in existence and to spread it as far as possible, it appears far more reasonable to assume that color fits in with this tendency, rather than that it gives a chance for the females to choose for their mates the most brilliantly colored.

Not only does color apparently contribute to the safety of the young, but certain special actions are sometimes discernible. Anyone who has hunted the turtle-dove—also called the mourning dove—has noticed that when the bird nesting on the ground is scared up, it will invariably fly close to the ground with one of its wings fluttering feebly, giving the impression that it is wounded. Upon reaching the spot fully fifty or a hundred yards ahead where the bird dropped, the hunter is amazed to discover that his prey is not there, nor can he usually find his way back

to the eggs or the young in the nest. In consequence the next generation is safe. Dogs and coyotes have been seen to scare up mourning doves on the nest, and in each case to be drawn away, either because the birds fly so low or because of the apparently injured wing.

Blackbirds will attempt to attract the attention of the intruder away from the nest by an injured wing, a dangling leg, or just a peculiar flying action. Doubtless nearly everybody who has tramped the hills or woods a great deal can give similar examples of how their attention was diverted in some way from the eggs or young presumably close by.

Now if this be the correct interpretation of color, it simply resolves itself into a part of natural selection—in this case for the safety of the next generation.

This theory, however, does not explain why fish of some species become more highly colored during the egg-laying season, and the writer has no explanation to offer. Here, too, he would rather give no explanation, leaving the question open for further investigation, than suggest what appears to him an unsatisfactory hypothesis.

It is well, also, to reëmphasize the fact that certain species seem to survive in spite of their color, not because of it. Not only is this apparently true of crows, ravens, magpies, and others, but of the white man himself. It would be difficult, if not impossible, to find a species or variety *with a poorer color*—more poorly adapted in color to its environment—than the Caucasian race. Certainly the Indian, the Negro, and even the Mongolian races, are better adapted because of pigmentation to protect themselves from intense direct or reflected light. It apparently just happened that along with a good brain came white color, and the latter factor, although not favorable, was not a sufficient handicap to keep the Caucasian from ruling and dominating most of the other races of the world.

If the various theories and examples given in this chapter do not seem reasonable to the reader, they certainly need not be accepted, since almost any interpretation made may be revised

in the light of further studies. The whole topic of coloration and sexual selection is a fascinating but difficult field for investigation, because it is so hard to get at the facts and to separate them from speculations and theories. This chapter is included because the discussion exemplifies the difficulties that beset the biologist in explaining satisfactorily some of the common phenomena of life.

QUESTIONS

1. Name some species in your region that seems to be surviving in spite of their color.
2. How would you go about to prove it?
3. Can you think of any other explanation for the lighter color usually found on the underside of most animals than that given in Thayer's Law?
4. If you disagree, why do you disagree with the writer's theory for the brilliant colors found on many male birds?
5. Have you a theory of your own to account for the brilliant color found on some fish?
6. Does it seem logical to you to assume that color, as well as many other traits and characteristics, should be for the purpose of insuring the success of the next generation?
7. What color or (colors) do you think the people of the world will have eventually? Why do you think so? Is there any evidence to that effect now?
8. Do you think the children of different races (white, red, black, yellow) should be segregated in school? Why or why not?
9. What factors are more important than color in differentiating the several races of mankind?
10. Would you present any of the facts in this chapter in a modified way to the children in the lower grades? In the upper grades? If so, what facts and how would you present them?

CHAPTER X

CLASSIFICATION

The chief reasons for classifying all living things, including mankind—The methods and principles of classification of plants and animals—Classification according to habitat, function, structure—Man's position in the animal kingdom.

History tells us that Alexander the Great, in his world-conquering campaign, detailed between one and two thousand men to bring back to his former teacher, Aristotle, all the new species of plant and animal life encountered. With many hundreds of new specimens pouring in upon him Aristotle was forced to develop some scheme of classification.

Of this much we are sure: Aristotle had access to and studied a very large number of hitherto unknown species. It is further known that Aristotle classified almost all the then known animals, placing each one in a definite group or class. Although it is now recognized that he made serious mistakes in this attempt to classify life, such as thinking that all blood was red,¹ yet his work stood for more than a thousand years as the standard and the authority for all workers in this field. To-day Aristotle is credited with being the father of biology, although there were many others before his time who were interested in the study of living things and doubtless many of the ideas attributed to him were common knowledge to the educated people of his day. Regardless of the latter possibility, Aristotle's contributions to biology were of very great value.

In the fields of art, music, literature, and religion, one may perhaps doubt that the Dark Ages ever existed, but in the field of science the justice of this designation cannot be questioned.

¹ Aristotle divided animal life into those animals with blood and those without blood.

For over a thousand years a very limited amount of progress was made in discovering nature's principles and facts. Only a very few people had any interest in the facts of nature, and among these the authority of Aristotle reigned supreme. It was not what the facts were that interested them nearly so much as what Aristotle had thought that they were.

It is recognized to-day that the only authority to which scientific men will yield is the authority of proved facts. Mere opinion, expressed even by those considered great in the eyes of the multitude, is worthless when compared to a fact firmly established by even the humblest person. The aim of science is not to substantiate existing opinions and beliefs but to discover facts irrespective of their bearing upon prevailing opinions and beliefs. Only upon such a basis can an enduring and beneficial science be built.

Upon such a basis the science of classification, *taxonomy*, can be safely built and only upon such a basis can man's place in nature be determined. The two reasons why biologists have attempted to classify living things are (1) for convenience in studying a vast number of different forms of life, and (2) to determine degrees of relationship.

Several minor attempts were made to classify living things after Aristotle's time, but little advance was made until the great Swedish naturalist, Linnæus, attacked the problem, publishing his famous book on plants, *Species Plantarum*, in 1753, and his book on animals, *Systema Naturæ*, in 1758.

The publication of these books and subsequent papers placed Linnæus as the pioneer in one of the half-dozen greatest advances in the history of biology. Although his work was not spectacular, his name ranks with those of the other great biologists, Darwin, Mendel, Pasteur, Van Leeuwenhoek, and Aristotle. These with Linnæus are considered by many to be the greatest names in a period of biological history extending through nearly twenty-four centuries.

Linnæus developed the system now used,—the binomial (or two-name) system of nomenclature based on structure. Before

Linnæus' time, animals and plants were classified chiefly according to habitat or according to analogy.

Perhaps the simplest classification is according to habitat or home location—land, underground, tree, and water. Although this method of classification is still resorted to in non-technical writings, a little investigation will show that it is a very poor system. For example, such animals as moles, burrowing owls, burrowing insects, angleworms, and rock-boring clams would be placed in the same group, since they live underground; but we now know that they have little in common—so little that taxonomists now place them in widely separate groups. According to the same system the following animals would have to be put in the water group, since they all live in water: fish, whales, seals, frogs, alligators, water insects, leeches, sponges, amœbæ. Now it is evident to one even slightly familiar with animal life that such a grouping places in the same class widely different species. Classification according to habitat had to give way to a better method.

Classification according to analogy or function came next and was popular with many biologists for a long time, since it was an improvement on habitat classification. However, according to this system bats, birds, and many if not most insects would have to be grouped together since they all fly. Careful study shows that the physical make-up of such animals is different—so different, in fact, that no one now attempts to place them together for scientific study. Similarly animals that jump were placed in a common group which would have to include so wide a variety as kangaroos, jack-rabbits, grasshoppers, locusts, and frogs. Now these animals are radically different in the way in which they are built—particularly the mammal members (kangaroos and jack-rabbits) as compared with those belonging to the insect group (grasshoppers and locusts). Evidently such a grouping is not one that reveals structural likenesses or significant relationships of any kind.

According to the same plan of classification based on function there were also swimming groups, running groups, and digging

groups. In each of these groups the members are so varied in their structure that grouping them together would not be justified.

The plan is further complicated by the fact that some animals, like the frog, could be placed in both the swimming and the jumping groups. Even man himself could be placed in at least three groups—running, jumping, and swimming, and possibly in a fourth also, the digging group. It is reasonable to demand that a plan of classification which is to work satisfactorily must be so built that an animal or plant cannot be placed in more than one group.

Due to the failure of the earlier attempts at classification on the basis of habitat and function, an earnest effort was made to find a principle of classification which could not be shaken by reasonable arguments and further advances in research. All biologists now agree that the cornerstone of classification must be anatomical structure or in other words, classification according to *homology*. Animals and plants with similar *structures* are now placed together in groups and subgroups, animals and plants with great variation in *habitat* and *function* often being placed in the same group.

The fact that structure or morphology is now recognized the world over as the main basis for classification does not mean that all other evidence is excluded. On the contrary, all evidence is accepted that can be shown to have scientific value. Considerable evidence for the classification of plant and animal life is often obtained from the study of the embryonic development of the various species and from the study of genetics. In the case of some of the bacteria and protozoa, classification has in many cases been built largely upon physiological activity. Several bacterial organisms look so much alike under the microscope that classification according to structure alone, under the present power of the microscope, is meaningless when we find that apparently similar organisms react in entirely different ways to food or other materials with which they come in contact. A good example is that of the tuberculosis germ and a common

hay bacterium. Structurally they are almost identical, and yet one is parasitic and often fatal to the life of the human organism, while the other is absolutely harmless. If the present power of the strongest microscope could be increased tenfold, enough

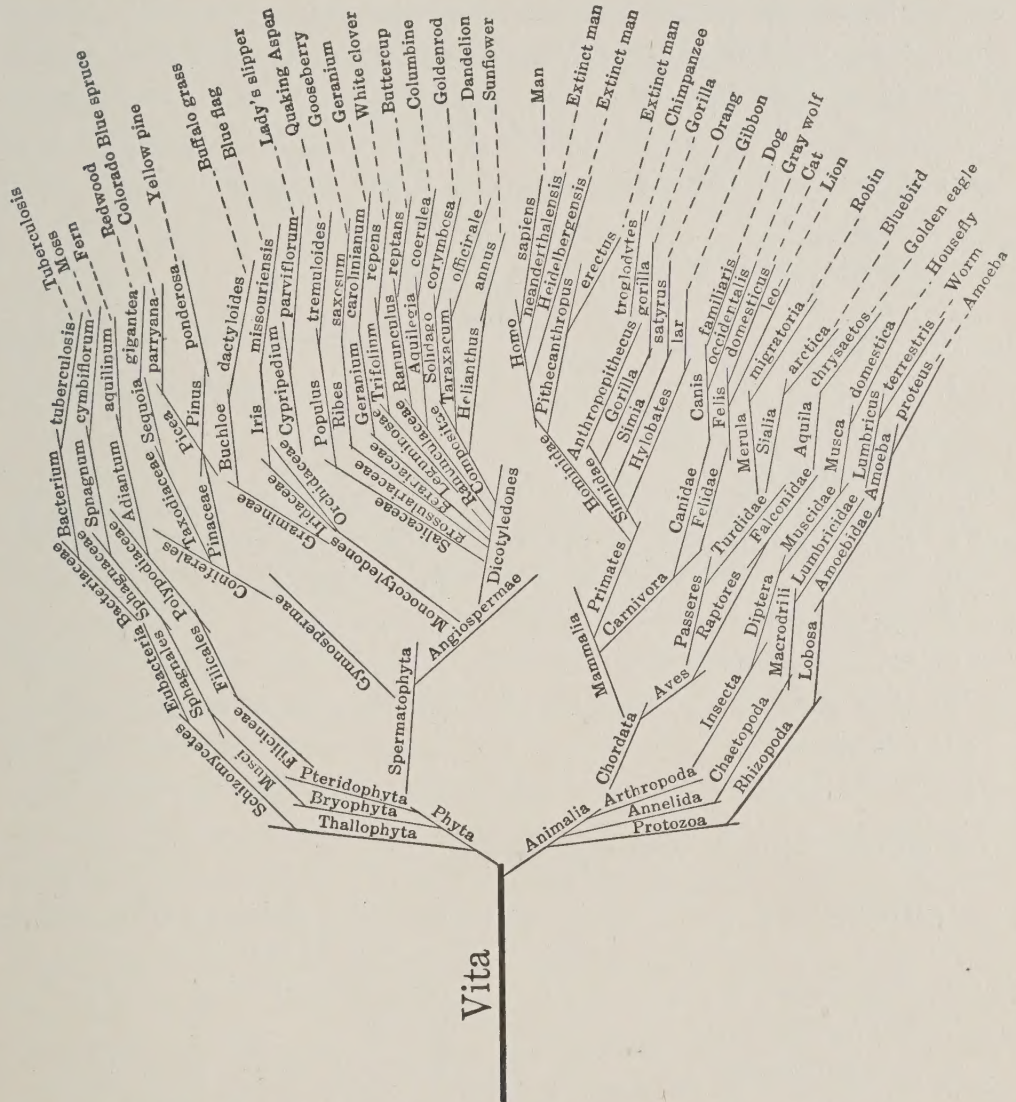


FIG. 17.—Diagrammatic drawing showing structural relationship between a number of plants, animals, extinct man, and modern man.

differentiation in structure might possibly be made out for a proper basis for classification according to structure. Until such time, however, the next best method must be used, in this case a functional rather than a structural basis.

Although classification according to structure dates back only one hundred and seventy-five years, yet in that time more than five hundred thousand animals have been named and about two hundred and fifty thousand plants.

All living things are thought of as belonging to the realm of life, *Vita*, as distinguished from non-living things. The realm, *Vita*, is divided into two main kingdoms, *Animalia* and *Phyta*.

The animal kingdom, *Animalia*, is generally divided into eleven *phyla* or divisions, and the plant kingdom, *Phyta*, into four *phyla*.

The animal *phyla* are:

PHYLA	TYPICAL REPRESENTATIVES
1. <i>Protozoa</i>	Amœba, paramecium, vorticella
2. <i>Porifera</i>	Sponges
3. <i>Cœlenterata</i>	Hydra, corals, sea anemones
4. <i>Platyhelminthes</i>	Tapeworm, flatworm, planaria
5. <i>Nemathelminthes</i>	Trichina, hookworm, ascaris
6. <i>Annelida</i>	Fishworm, leech
7. <i>Ctenophora</i>	Sea walnuts
8. <i>Echinodermata</i>	Starfish, sea urchins
9. <i>Mollusca</i>	Clams, oysters, snails
10. <i>Arthropoda</i>	Insects, lobsters, crabs
11. <i>Chordata</i>	Fish, frog, bird, cat, man

The plant *phyla* or divisions are:

1. <i>Thallophyta</i>	Bacteria, yeasts, lichens, mushrooms, puffballs.
2. <i>Bryophyta</i>	Mosses, liverworts
3. <i>Pteridophyta</i>	Ferns
4. <i>Spermatophyta</i>	Mustard, clover, geraniums, daisy, sunflower

Slightly varying classifications and names are used by some taxonomists, but the above scheme has been almost universally adopted.

Each phylum is again divided into *classes*; the classes again into *orders*; the orders into *families*; the families into *genera*; and

the genera into *species*. Occasionally subfamilies, suborders, and subclasses are created for convenience, but these need not be considered here. Often varieties of species are recognized, particularly of domesticated animals and cultivated plants. A common method of arrangement to show the value of each division and its relation to the other divisions is as follows:

Realm

Kingdom

Phylum

Class

Order

Family

Genus

Species

(Sometimes varieties)

It should be said that the terms species, genus, family, order, class, phylum, and kingdom are more or less arbitrary terms to indicate relative difference in *size* and *importance* of the several groups. Even the person not well acquainted with the method of classification knows much more about the subject than he is aware. Let us study the common dog and see how he comes to be classified as he is.

In common with all living things the dog belongs to (*a*) *Vita*, in common with all other animals to (*a*¹) *Animalia*, since it moves, digests its food, and otherwise behaves like a typical animal. That *Animalia* is a subdivision of *Vita* is obvious since "life" is a more comprehensive term than either "animal life" or "plant life." The dog, since it has a notochord (most of the members of this group have backbones) belongs (*a*²) to the phylum *Chordata*, which is a subdivision of the kingdom *Animalia*. It is a subdivision because it is quite evident that the term "backboned (or back-cartilaged) animal" is less inclusive than the term "animal." Since the dog has mammary glands, hair, and three bones in the ear, it also belongs (*a*³) to the class *Mammalia*, which is a subdivision of *Chordata*. It can be quite readily understood that "mammal" is less inclusive than the

division "backboned" or "back-cartilaged" since other complex organisms are also backboned or back-cartilaged, and therefore *Mammalia* is a subdivision of *Chordata*. The classes of *Chordata* usually recognized are:

CLASSES	TYPICAL REPRESENTATIVES
<i>Hemichorda</i>	Balanoglossus
<i>Tunicata</i>	Sea squirts, tunicates
<i>Cephalochorda</i>	Amphioxus
<i>Cyclostomata</i>	Lampreys, hags
<i>Pisces</i>	Trout, herring, perch
<i>Amphibia</i>	Frog, toad, salamander
<i>Reptilia</i>	Lizard, snake, turtle, alligator
<i>Aves</i>	Bluebird, eagle, ostrich
<i>Mammalia</i>	Dog, ox, whale, chimpanzee, man

The dog further belongs (a^4) to the order *Carnivora*, since it is a flesh eater and has flesh-eating structures such as canine teeth and a digestive system suited to fleshy food. *Carnivora* is a subdivision of *Mammalia* since all of the flesh-eating animals have mammary glands and hair, the chief characteristic of mammals, but not all of mammalia have carnivorous teeth. The dog is also (a^5) a member of the family *Canidæ*, a special type of carnivorous animal and therefore a subdivision of *Carnivora*. But our scientific designation of the dog as *Canidæ* is not yet detailed enough; therefore it is necessary to have other subdivisions. Accordingly the dog belongs (a^6) to the genus *Canis*, a type of the dog family, *Canidæ*. Even this detailed subdivision is not quite sufficient, for wolves and coyotes also are members of the genus *Canis*. We shall have to make one more subdivision (a^7) to be specific and hit upon a name that describes only the common dog. This last subdivision is known as species and in this instance is called *familiaris*.

No other animal in the entire world comes under the designation of *Canis familiaris*.¹

It is true that in the case of dogs, cats, horses, sheep, cattle,

¹ A generic name (such as *Canis*) is always capitalized; a name of a species (such as *familiaris*) coming after the generic name is not capitalized.

swine, poultry, corn, wheat, cabbage, and many other domesticated and cultivated types, as well as in a few wild forms, the term "variety" has to be introduced and even the term "breed" or "strain" in order to describe exactly the type in question. In the case of poultry, about two hundred standard varieties are recognized by poultry fanciers. There are several score varieties of pigeons, perhaps three dozen or so distinct varieties of cattle, a number of different kinds of horses, sheep, swine, and scores of varieties of dogs and cats. In the plant world there are numerous varieties of corn, wheat, and oats. The significant thing about these varieties is the fact that they can only be maintained as such, in pure form, either by careful selection and isolation by man, or by natural selection and isolation on an island or a long distance away from related varieties during the breeding season. Indeed, a variety is often described as being different from a species by the fact that the former will readily interbreed with other varieties of the same species while the latter never or seldom will interbreed and produce offspring to the second hybrid generation inclusive. Often two species such as the jack and the mare will interbreed and have offspring (in this case the mule), but a second hybrid generation is almost never produced since the hybrid is infertile.

Returning to the scientific nomenclature of the dog, we find that its complete name is *Vita, Animalia, Chordata, Mammalia, Carnivora, Canidæ, Canis, familiaris*, but when writing of the common dog in scientific literature, one uses only the last two terms, the genus and the species, because if one is sufficiently acquainted with scientific literature to know that the dog is *Canis familiaris*, he is presumably well enough informed to know that it belongs to the dog family, *Canidæ*; to the order *Carnivora*; to the class *Mammalia*; to the phylum *Chordata*; and to kingdom *Animalia*. It is because only the genus (generic) and species (specific) names are given when describing an animal or plant scientifically, that the system now universally used is spoken of as the "binomial" system of nomenclature.

Tracing the scientific names of the gray wolf, we find that it,

too, belongs to *Vita* since it is alive; to *Animalia* since it is an animal; to *Chordata* since it has a backbone,¹ to *Mammalia* since it has mammary (milk) glands and hair; to *Carnivora* since it has the teeth of a flesh-eating animal; to *Canidæ* since it has dog teeth and all of the other special traits of the dog family; to *Canis* since it is a true wolf or dog. It does not, however, belong to the species *familiaris*, due to the fact that it differs from the common dog in a few points—minor, to be sure, but of sufficient importance to make it a separate species. The gray wolf belongs to the species *occidentalis* and therefore it is called *Canis occidentalis*, which distinguishes it from the Asiatic wolf, the African dog, the Australian dog, and all the other dogs and wolves.

Since both the domestic dog and the gray wolf are members of the same genus, because of their similarity in structure, we say that they are closely related. In fact, the domestic dog and the gray wolf are as closely related as it is possible to be and yet belong to separate species. Only varieties can be more closely related and, as stated above, they belong to the same species and therefore readily interbreed.

Anyone slightly acquainted with animals would say that the Virginia fox is a member of the dog *family* and upon examination of the structures of his body we find that he is. He has the following complete scientific name: *Vita*, *Animalia*, *Chordata*, *Mammalia*, *Carnivora*, *Canidæ* (the “family” name), *Vulpes*, *virgianus*. We find that all the names are identical with those of the domestic dog except the last two, the genus and the species. Therefore, we say that the fox and dog are closely related but not so closely as are the dog and wolf, since the latter belong both to the same family and the same genus, whereas the former have only the family in common.

If one were to ask an intelligent layman if he thought that the dog and cat were related, he would probably say Yes, and then point out some quite obvious external differences. A scientific analysis shows that the cat has the following names: *Vita*, *Ani-*

¹ In some chordates, the “backbone” is not ossified; that is, it is not actually a bone but a cartilage; for example, the sharks and rays.

malia, Chordata, Mammalia, Carnivora, Felidæ, Felis, domesticus. We thus see that the dog and cat both belong to the five largest subdivisions, *Vita, Animalia, Chordata, Mammalia, Carnivora*, but not to the same three subdivisions of family, genus, and species. The dog belongs to the *Canidæ* family, while the cat is a member of the *Felidæ* family. This scientific analysis shows the dog and the cat to be more distantly related than the dog and the fox, a conclusion any intelligent person not trained in scientific biology would be likely to reach.

Again, nearly any intelligent person would recognize some similarities in the bald eagle and the dog; yet if questioned, he would be almost certain to say that there were more differences. This statement is borne out by the fact that the bald eagle and the dog have only the three largest subdivisions in common, *Vita, Animalia, Chordata*, while they represent five different subdivisions—class, order, family, genus, and species. Perhaps the outstanding similarity is the fact that both have backbones and internal skeletons. The bald eagle belongs to the class *Aves*; order, *Raptores*; family, *Falconidæ*; genus, *Haliæetus*; species, *leucocephalus*.

A close examination of the scientific data concerning classifications shows that the fishes, the amphibians, and the reptiles differ from each other in about the same degree that birds differ from the mammals; each one belongs to a separate class of the phylum *Chordata*.

If a comparison is made between the dog, which is a member of the highest phylum, *Chordata*, and a house fly, a member of the next lower phylum, *Arthropoda*, nearly anyone would say that the differences are numerous and outstanding and probably would have difficulty in naming similar traits, although it is well known to biologists that both forms have jointed legs, a head, thorax, abdomen, are segmented, and reproduce their kind in much the same way. Both phyla produce eggs and are typically fertilized by sperm cells.

According to the binomial system of classification, the dog and the house fly, which is a typical member of the phylum *Arthrop-*

oda, have in common the traits of only the two largest groups, *Vita* and *Animalia*, whereas they represent six different divisions:—phylum, class, order, family, genus, and species. Again this only says in rather precise scientific language what every intelligent observer knows, namely, that only a few of the fundamental traits of animal life are common to both the dog and the house fly.

On examining the *Amæba proteus*, a common member of the lowest animal phylum, *Protozoa*, we find that it is difficult to show similar traits and easy to point out great differences separating it from the dog. About the only outstanding similarities are that both are made up of a cell or cells, both eat as typical animals by taking in solid food, at least part of the time, and both move about, a trait which is restricted mostly although not entirely to animals. The dog and the amœba belong to the most widely separated animal phyla, the *Chordata* and *Protozoa* respectively, and have in common only the realm *Vita* and the kingdom *Animalia*, differing on all the other subdivisions.

When we examine the plant world, we find that it also is divided into eight divisions, each succeeding one smaller than the former. These eight divisions will again be called realm, kingdom, phylum, class, order, family, genus, and species, although it is common to find other names used to designate the same groups, particularly for the terms phylum and class.

If we take the common yellow or rock pine, *Pinus ponderosa*, as our key specimen in the plant kingdom (as we used *Canis familiaris* in the animal kingdom), we find the following to be true about the former's taxonomic status.

First of all the plant is alive and hence belongs to the living realm *Vita*, since it is irritable, grows, and reproduces its kind, traits common to all living things. The yellow pine is a plant, *Phyta*, because it behaves in every way like a typical plant. It further belongs to a particular division of *Phyta* called *Spermatophyta* since it produces true flowers and seeds even though these are not so conspicuous as are those of the majority of flowering plants which have petals. The *spermatophyta* differ from the

rest of the plant world in that no other group produces true flowers and true seeds.

Since there are thousands of plants that produce flowers and seeds, it is obvious that we must make other subdivisions before we definitely and accurately name the yellow pine. The type of seed produced shows that it belongs to the class, *Gymnospermæ* as contrasted with *Angiospermæ*. The former term means naked-seeded while the latter that the seeds are covered or inclosed in a "pod" as are bean and pea seeds. If one examines a pine cone, one can readily see that the two seeds found on each scale are not inclosed by the scale but lie upon it in much the same way that a small insect might lie on a roof under one shingle but upon another. Such an insect would not be thought of as in the shingle roof but rather between the shingles of the roof. For about the same reason the pine seeds are said to be naked—that is, not inclosed by the scales of the pine cone.

Many plants beside the yellow pine belong to the class, *Gymnospermæ*, and therefore we must subdivide again, this time into the order *Coniferales*. This is to distinguish it chiefly from other orders such as *Ginkgoales*, a type that does not produce a true cone. However, since all of the cedars, cypresses, spruces, firs, Douglas firs, as well as the pines, belong to *Coniferales*, we must make a still smaller subdivision, this time into the family, *Pinaceæ*. This family is typified by needle-like leaves and true cones. Since the spruces, firs, and Douglas firs also have needles and true cones, we must further subdivide into the genus *Pinus*. The spruces, firs, and Douglas firs are now eliminated since only those members of *Pinaceæ* having needles in fascicles or bundles belong to *Pinus*.

There still remain several dozen different forms of plant life that could qualify under *Pinus*, and so still one more subdivision must be made into the species *ponderosa*. The latter term, it is evident, means large in size.

Therefore we find the common yellow pine has the following complete name: *Vita, Phyta, Spermatophyta, Gymnospermæ, Coniferales, Pinaceæ, Pinus, ponderosa*. No other form of life

can possibly have this name, although many pine types have everything in common with the yellow pine except the last distinguishing characteristic, as, for instance, the edible pine, *Pinus edulis*. This is one of the pines that produce piñon nuts so relished by the Indians of the dry plains and mesas.

The average observer would say that the yellow pine and the piñon pine are more nearly alike than the yellow pine and the Colorado blue spruce, *Picea parryana*. This conclusion is borne out by the fact that similarities of structure place the two species of pines in the same genus as well as in the same family, whereas the yellow pine and the spruce have only family traits in common.

There is obviously a greater difference between the yellow pine and black bread-mold than between the yellow pine and the Colorado blue spruce. The latter two although differing widely on many important points belong to the same family *Pinaceæ*, while the black bread-mold belongs to even a different phylum, *Thallophyta*. Thus the black bread-mold and the yellow pine have only two divisions in common, *Vita* and *Phyta*, differing on the six other divisions.

The question may be raised as to the relationship between the yellow pine or any other distinct member of the plant kingdom and the dog or any other distinct member of the animal kingdom. The answer we now see is fairly easy. Since these two differ not only as to Species, Genus, Family, Order, Class, Phylum, and even Kingdom, it is obvious that the similarities cannot be many. In fact, there seems nothing more in common than the fact that both are built out of units called cells, which come into being by the process of "mitosis" (indirect cell division) and both have the power of growth, reproduction, and irritability.

At this point one may well ask, "Where does the human being come in? To what other animals is he most closely related and how closely?" First of all, man belongs to *Vita* since he is alive; to *Animalia* since he is an animal; to *Chordata* since he has a backbone; to *Mammalia* since he has mammary glands, hair, and three bones in the ear. Thus far all will agree. A slight

knowledge of classification enables us to discover that he and his closest relatives are so different from the bats, the whales, the hoofed animals, the toothless mammals, and the gnawing animals that a separate order must be created called the *Primates*, meaning the highest or most important animals—those with well-developed central nervous systems. Since the physical structure of man is so nearly like that of other animals which also belong to this order and since man is different from all of them to a degree, a distinct family had to be created, called *Hominidæ*. Mankind also belongs to the genus *Homo* and the species *sapiens*. *Hominidæ* means man family; *Homo* means man and *sapiens* means wise.

If we compare the dog with the human being, we find that they both belong to the realm of the living called *Vita*, to the kingdom called *Animalia*, to the phylum called *Chordata*, to the class called *Mammalia*, but to different orders. The dog belongs to the order *Carnivora*, while man belongs to the order *Primates*. If, however, we compare the chimpanzee with the human being, we find that the former belongs to the order *Primates* also, since in the structural make-up of the bones, muscles, and organs, the two are almost identical.

While there are some authorities in the field of the *Primates*, such as the late Professor Wilder¹ of Smith College, who would put the chimpanzee, the gorilla, the orang-utan, the gibbon, and man in the man family, *Hominidæ*, the majority of workers in this field put the first four into the family *Simiidæ* and man alone in the family *Hominidæ*. Further study shows the chimpanzee to have the following scientific names beginning with *Primates*, *Simiidæ*, *Anthropopithecus*, *troglodytes*. The gorilla has the same family name (*Simiidæ*) but belongs to the genus *Gorilla* and to the species *gorilla*. The orang-utan has also the same family name but belongs to a different genus and species, in this case to *Simia satyrus*. Likewise the gibbon belongs to the same family but has a separate genus and species, *Hylobates lar*.

It is thus evident that the human being belongs not only to a

¹ Wilder, H. W., *Pedigree of the Human Race*. Henry Holt and Co., 1926.

separate species, but also to a separate genus, *Homo*, and to a separate family *Hominidæ*. While it should be kept in mind that there have been other species of human beings on earth such as *Homo neanderthalensis* and *Homo heidelbergensis*, it is generally agreed that all living representatives of the genus *Homo* belong to the one species *Homo sapiens*.

Conservative paleontologists state that the separation between man and the apes occurred certainly not less than five hundred thousand years ago. In other words, *Homo sapiens* has been sufficiently human to be recognized as such for at least a half million years. If we allow thirty years to a generation, then there have been at least sixteen thousand generations of human beings. Classification (together with embryology, morphology, paleontology, and genetics) further shows that the human being did not descend or ascend from the ape but that both groups have had distinct and separate developments. Neither group has been ancestral to the other but both go back to a common progenitor.

That the human being has changed physically in the past is now well established.

The accompanying drawing (Fig. 18) illustrates the conclusions of the scientists regarding the derivation of the order *Primates* and the differentiation of the order into distinct groups and species.

Figure 19 illustrates what is believed by one prominent school of biologists to be the relationship existing between some of the important divisions of life. It should be said here that careful work has not been done on all species, genera, or even families; so the exact relationship of all groups is not known. Enough evidence, however, has accumulated from thousands of species and from many angles and sources to confirm the main points.

In an earlier paragraph it was said that there were once species of man on earth other than *Homo sapiens*. The reader doubtless has asked the question, "What became of these other species of men?" Since no written history is available concerning them we can only surmise what may have happened. Entire tribes may

EVOLUTION OF PRIMATES

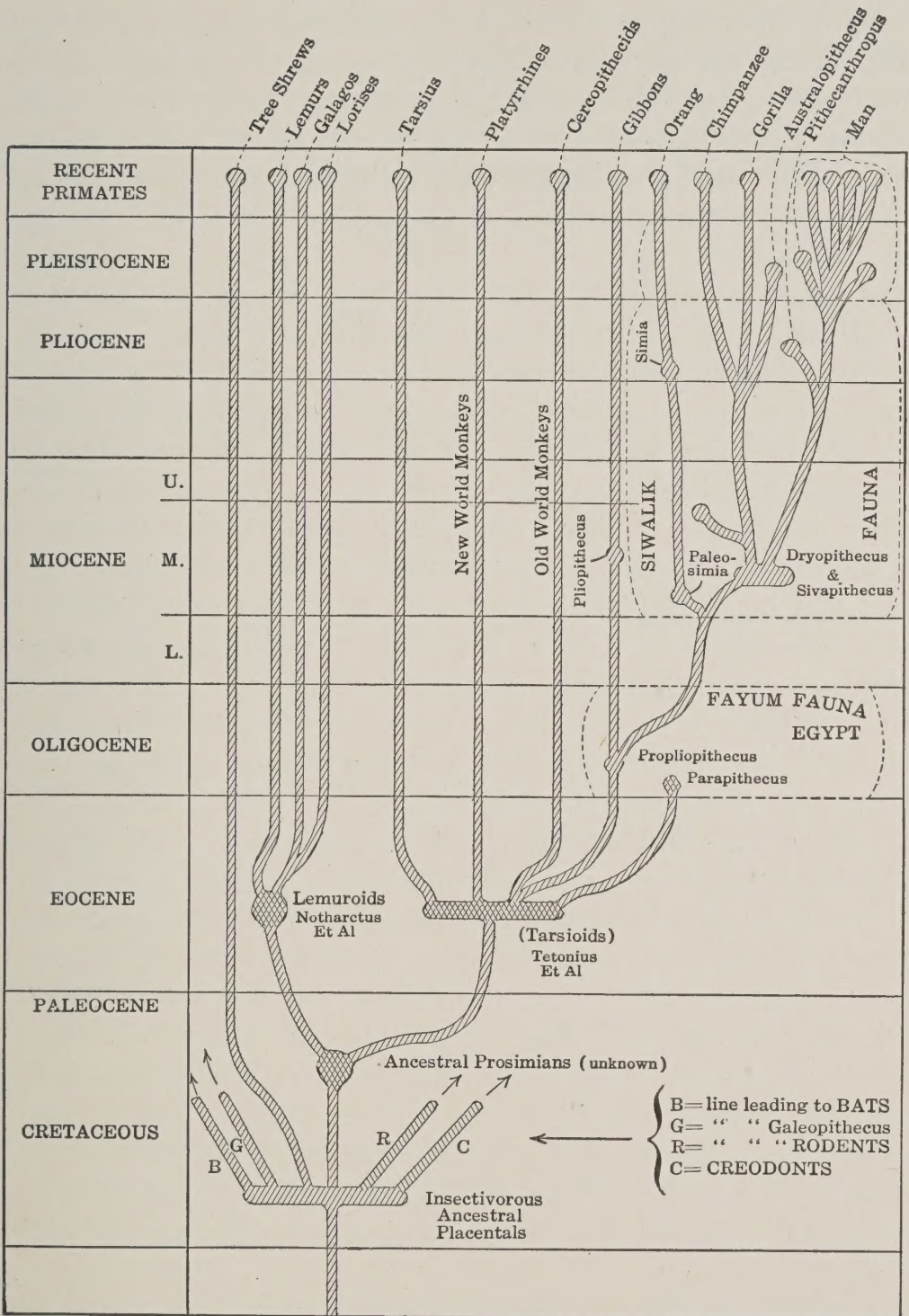


FIG. 18.—(Modified from Sonntag, partly after W. K. Gregory and J. H. McGregor.)

have been exterminated by pestilence or famine. There is also the possibility—indeed, the probability—that entire tribes have been exterminated by warfare. In a struggle with other species, *Homo sapiens*, because of his superior brain and intelligence, may have been able to crush out his less fortunate competitors, leaving him the sole survivor of the genus *Homo* and the family *Hominidæ*.

Another important question has probably arisen in the student's mind, Why are Latin and Greek names used to classify plants and animals? Latin and Greek are "classical" languages among the peoples of the Western world, and, until recent years, all educated people were familiar with them. When scholars of different countries made discoveries they could communicate their discoveries to other scholars in terms that these other scholars, all over the civilized world, could understand. The fact that Latin and Greek are "dead" languages as well as classical languages added to the advantage of using them for scientific nomenclature. Living languages change to some extent from generation to generation. Words change their meanings. But a "dead" language is fixed, so that the same meanings may be preserved in scientific descriptions and references and the danger of confusion through changed meanings, which would be present if any living language were used, is thereby avoided. It should be kept in mind that the binomial system was adopted nearly two hundred years ago, long before the Oriental nations began to study science; hence they did not have a voice in deciding upon the language adopted. If they had had a voice, it is possible that Latin and Greek would not have been chosen or else that there would be at least two scientific "world" languages—one for the Orient and the other for the Occident. Fortunately, the Orientals have adopted the system of the Occident, and we have a real world language for naming all plants and animals.

The first person who describes a new species of animal or plant life and who publishes at least ten copies of the description has the right to name it. This name, if consistent with the princi-

ples of biological nomenclature, is then forever recognized the world over as the only correct scientific name, no matter how humble a position the person giving the name may occupy. Names of species and varieties are often derived from the names of the person making the first discoveries.

QUESTIONS

1. Have you ever thought of any other method of classification than that given in this chapter? If so, what or how?

2. Why is it that we do not find land animals with external skeletons large in size?

3. What reason can you give for the fact that no flying bird weighs as much as fifty pounds?

4. Why do you think that there are animals of uncertain relationship such as Rotifers?

5. What would happen to biological research work if for some reason the present system of nomenclature were dropped altogether?

6. Why are most bacteria usually considered a lower form of life than such animals as the amoeba?

7. Do you know of any real disadvantage in classifying man with the other animals? What?

8. Can you name advantages, other than those given in this chapter, for classifying man with the other animals? What?

9. To what extent should children in the lower grades be informed of their relationship to the other forms of life? In the upper grades?

10. Can you suggest how children might be injured by learning of the facts presented in this chapter?

CHAPTER XI

THE PRIMATES

Are there structures and functions in man not found in the apes?—Man's nearest relatives—Man's relationship to the apes and monkeys—Extinct and primitive human species and races—Probable reasons for the extinction of races and the other human species—The child as a typical primate.

The order Primates is of particular interest because it includes all of the human species and varieties, both living and extinct, the four anthropoid apes which are so strikingly similar to man, and all the lemurs and monkeys, large and small, of both hemispheres.

As stated in the chapter on Classification, the order Primates is a subdivision of the class Mammalia. According to most authoritative students of this order, it is divided into two sub-orders, *Lemuroidea* and *Anthropoidea*. Each of these sub-orders is in turn divided into families (sometimes sub-families), genera, species, and sometimes varieties.

A typical classification of the Primates is as follows:

ORDER PRIMATES

Sub-Order: **Lemuroidea** ("mischief-making spirits")

Family 1: LEMURIDÆ—about 35 species and varieties,—in India, Africa, Madagascar—True lemurs, mouse lemurs, loris babies, and bush babies.

Family 2: CHEIROMYIDÆ—only one species—in Madagascar—Daubentonia or "aye-aye."

Family 3: TARSIIDÆ—only one species—in East Indies, Philippines—Tarsius.

Sub-Order: **Anthropoidea** (man-form primates)

Platyrrhini (flat-nosed monkeys—American forms)

- Family 1: CALLITRICTIDÆ—numerous species and varieties—in Central and South America—Marmosets.
- Family 2: CEBIDÆ—numerous species and varieties—in Central and South America—Howling, squirrel, night, saki, cebus, and spider monkeys.
Catarrhini (straight-nosed monkeys—Old World forms)
- Family 3: CERCOPITHECIDÆ—Enormous number of species and varieties—in India, East Indies—Macaques, magabeys, guenons, semnopithecus, dog-faced baboons.
- Family 4: SIMIIDÆ—about 30 species and varieties—in Africa, Asia, East Indies—Gibbons, orang-utans, gorillas, and chimpanzees.
- Family 5: HOMINIDÆ—only one living species—all over the world—*Homo sapiens* (also extinct species: *Pithecanthropus erectus*, *Homo heidelbergensis*, and *Homo neanderthalensis*).

Perhaps the first point that should be cleared up concerns the reasons for putting all the lemurs, monkeys, apes, and man, both living and extinct, into the order Primates. If we study the structure of the members of this order, we are impressed by their great similarity. Even though some of the smaller monkeys weigh less than five pounds and some individual gorillas as much as five hundred pounds, they are, nevertheless, very much alike in structure. In fact, it is quite impossible to find any fundamental part present in one that is absent in the other. To be sure the tail may be very long and prehensile in one and apparently absent in the other, but even here the difference, since all anthropoids have at least four tail-bones, is in degree only. The front and hind legs may be extremely long in proportion to the rest of the body, as in the spider monkeys, and shorter in others, as in the chimpanzee; but this difference again is only a matter of degree and is comparatively superficial.

If we select any of the monkeys or apes for comparison with man, we find great similarity in physical structure, particularly when comparing the gibbons, orang-utans, gorillas, and chimpanzees. It is impossible to find any bone, muscle, blood vessel, nerve, or organ that is present in man that is not also present in

the apes. Not only are all these parts found in man and in the apes, but the parts themselves are nearly identical except in relative size or proportion.¹

Often the question is asked, "What monkey or ape is the most like man?" Nearly everyone qualified to express an opinion states that the gorilla and the chimpanzee are about equal in their similarity to man, with possibly the evidence slightly in favor of the chimpanzee. If one tabulates in detail the relative size and position of the parts of the body of the human being and the chimpanzee, one is amazed at the close correlation. Both have exactly the same number of bones in the head in the same relative position, and of about the same size; both have the same number of neck vertebræ, thoracic vertebræ, abdominal vertebræ, pelvic vertebræ; both have the same number of tail bones greatly reduced; both have the same number of bones in the arm—phalanges, metacarpals, carpals, ulna, radius, humerus; both have the same number of bones in the leg—phalanges, metatarsals, tarsals, tibia, fibula, femur; both have the same number of bones with very similar shape in the pelvic and pectoral girdles; both have similar sternums, knee caps, and ear bones. In fact, except for some parts of the skull, the bones of the chimpanzee would almost fit the human being. The same general statements can also be made for the muscles and other organs of the body, although, of course, one would hesitate to exchange the central nervous system, supposing such an operation were possible, even if the difference were only a matter of degree. The superiority of mankind rests almost exclusively in the nervous system, and more particularly in the greatly enlarged cerebrum. It is this part of the brain that is developed in the human being to a point far beyond that reached by the highest ape.

Next to the gorilla the orang-utan,—with the gibbon coming third,—is structurally most like the human being. As one

¹ It has been asserted that there is a certain muscle in the foot of man, called *Peronæus tertius*, that is not present in the apes. However, recent careful dissection of two gorillas has shown this to be untrue. Without any exception there is an almost exact parallelism of parts in man and in the apes.

descends in the scale of primate development to the lemurs, one finds greater and greater differentiation from man, but even in the lowest primates the structural similarity is noticeable.

The structural similarity of the primates is noticeable not only to the biologist but to every unprejudiced observer. If one listens, say, for an hour, to the conversation of those who come to see monkeys in a cage at a park, one is almost certain to hear repeatedly such statements as these: "They certainly do look much like humans," or "You could almost believe they were primitive or wild men." In Africa, Asia, and the East Indies, where the four anthropoid apes are to be found, travelers note that the natives of the region nearly always refer to these anthropoid apes as "wild men" or "escaped men." Even though they may never have heard the term, biology, they note the resemblances which eminent men of science have proved by careful investigation and research.

One is also sure to hear references to the "missing link" in discussions concerning man's animal ancestry. The term, "missing link," is a very poor one and also a very vague one covering a mass of ignorance.

In the first place, there is not so complete a gap in man's line of ancestry from the lower forms as the term "missing link" indicates. In the second place, those who use this very poor term almost always mean by "missing link," an animal about midway between the living apes and man. Now no biologist of standing would maintain that mankind came from any of the living apes or from their close existing relatives. The present highly specialized living apes or extinct forms were not ancestral to man any more than man was ancestral to the apes. It is believed, however, that both of these extremely highly specialized families, *Hominidæ* and *Simiidæ*, represent divergent types having common ancestry. There is much evidence which a specialist in this field can point out to substantiate such a statement.

The phyletic tree of the anthropoid apes and mankind illustrates in tree and picture form what is believed to be the

PHYLETIC TREE — ANTHROPOID APES AND MANKIND

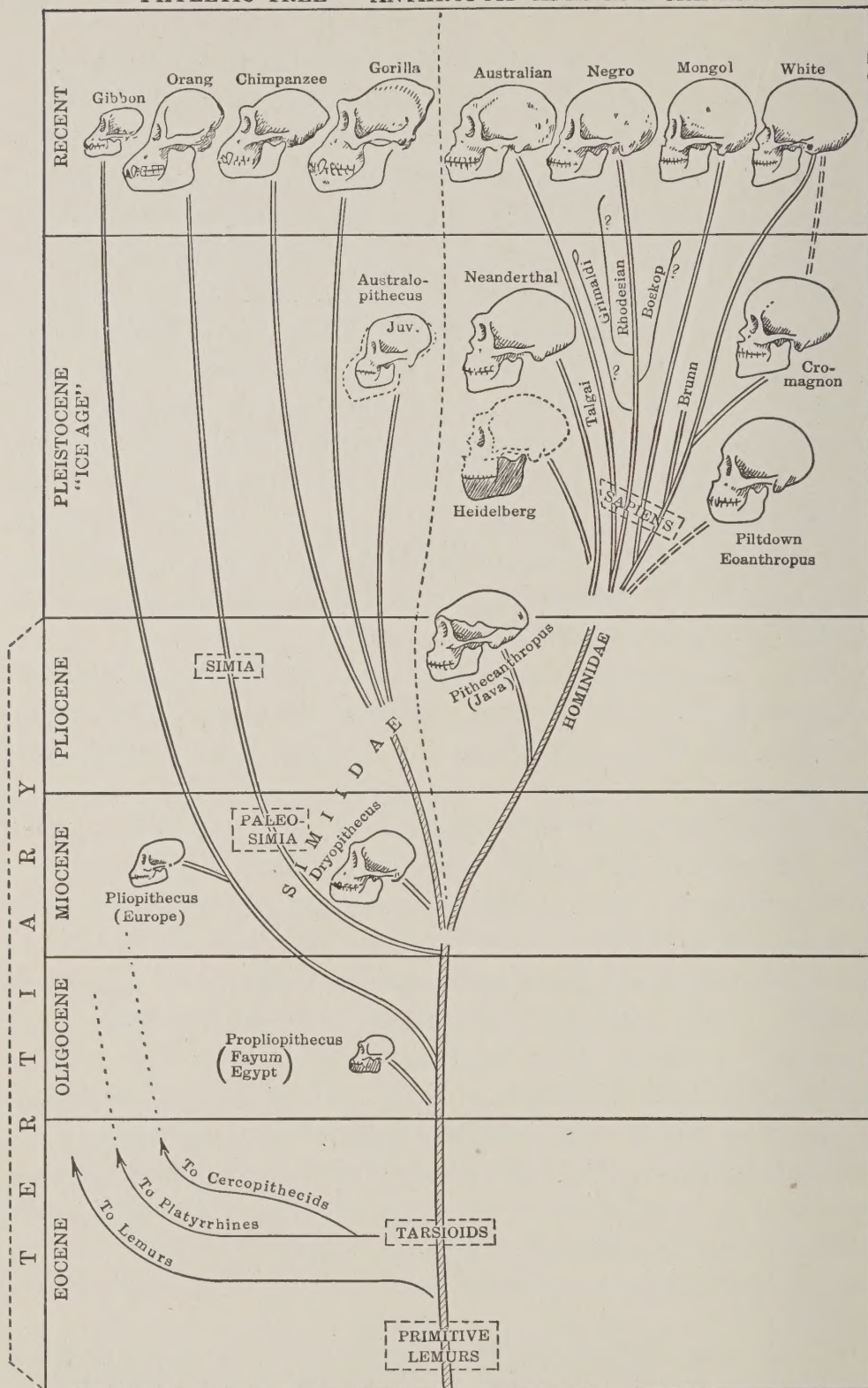


FIG. 19.—Modified from W. K. Gregory by J. H. McGregor.

relationship existing between the apes and the various types of mankind. The advantage of showing relationship in this way over the other types lies in the drawing of the skulls of the various species and varieties, and in the indication of the probable time of appearance of each species. The reader will note that not all the lines are completely connected, which means that the careful scientists who made the chart, are not willing to say that all the evidence is in; and therefore it is possible that changes in the diagram may be made later.

Perhaps the most striking thing about the chart is the suggestion that more than one species of mankind has been on earth, although only one species is now living, divided into four great divisions each of which has a number of varieties. Three of these species, *Homo sapiens*, now living, *Homo heidelbergensis*, and *Homo neanderthalensis*, are human beings, while *Pithecanthropus erectus* is much lower in the scale of development although it is now thought by most anthropologists to be more like a human being than like an ape. Piltdown man and Crô-Magnon, as well as the Rhodesian, Grimaldi, and Boskopmen are quite clearly only varieties of our species *Homo sapiens*. The status of the last three is still somewhat questionable, although at any time light may be thrown on the subject by the workers now in the field.

From this discussion and chart, it can be seen that the term "missing link" has been too carelessly used by the uninformed. It is clear, also, that the evidence for some of the relationships pictured is far from complete. It can be said with a high degree of certainty, however, that as new fossil specimens have been discovered from time to time, man's kinship to the other primates has been more and more firmly established.

Another noticeable fact is that the makers of the chart did not put the white race above all the rest. Although the four important races of mankind are put on the same level in the chart, that does not mean that all races are of equal potential intelligence. Few students of the problem would contend that the Australian Bushman is at all close to the Caucasian in

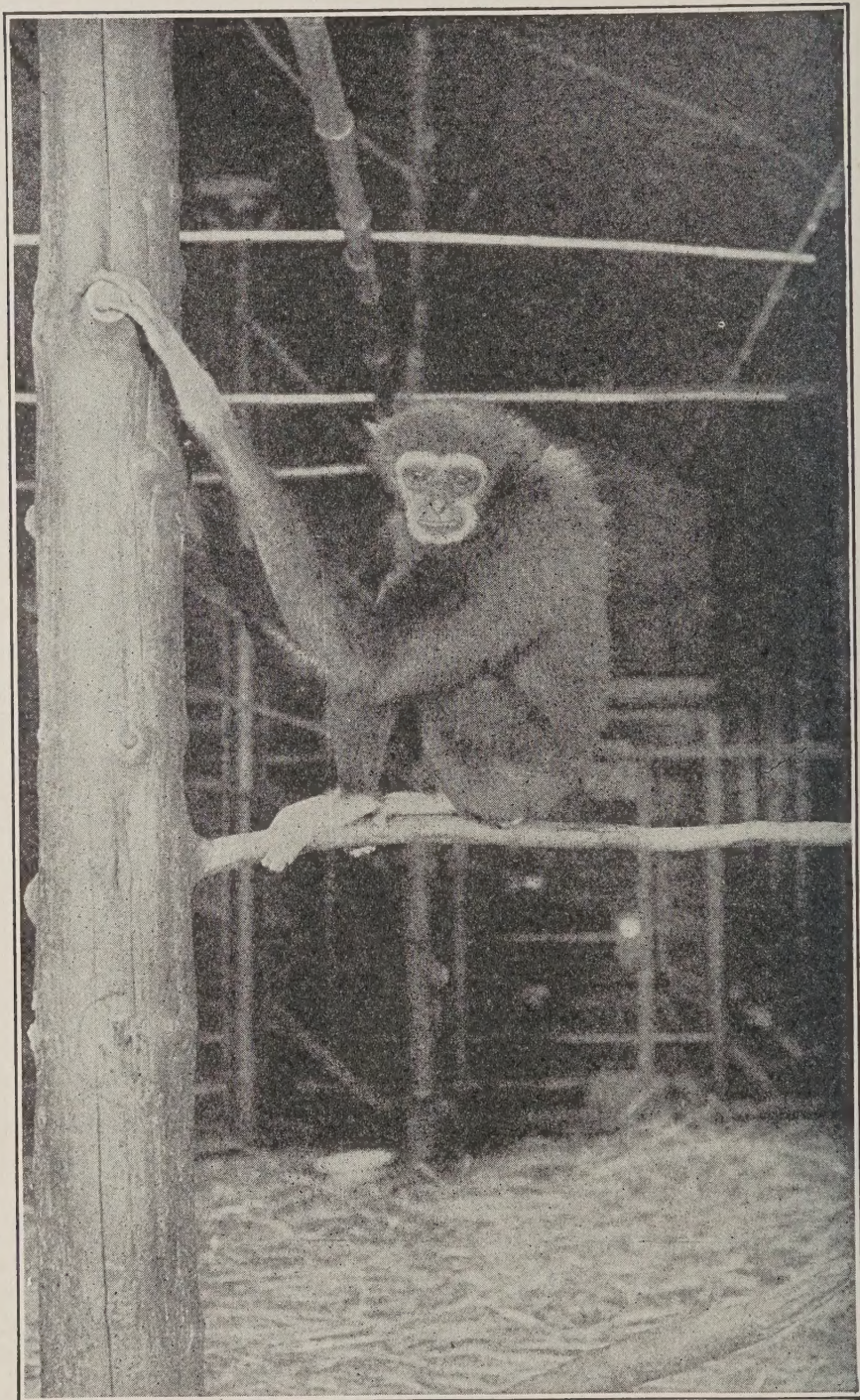


FIG. 20.—Gibbon, *Hylobates lar*, southeastern Asia. (From Lull, photograph from the New York Zoölogical Society.)

intelligence. However, those who have associated with the Chinese, the Indians from India, and even some of the Indian tribes from North America, the Japanese, and other non-Caucasian groups, recognize that many of these peoples have mental powers quite equal to our own. To be sure, we usually think of



FIG. 21.—Orang-utan, *Simia satyrus*, Sumatra and Borneo. (From Lull, photograph from the New York Zoölogical Society.)

their civilization as inferior to ours, but this is clearly a matter of social rather than of biological inheritance and in the case of the Japanese, even the question of “higher” or “lower” civilization would be hard to answer. We can say very positively that the white race, as a whole, is not inferior to any other race and, *possibly* is superior to some types. There is general agreement, however, that the differences among the individual members of any major race are wider, and probably more significant, than

the differences among the averages representing the several major races.

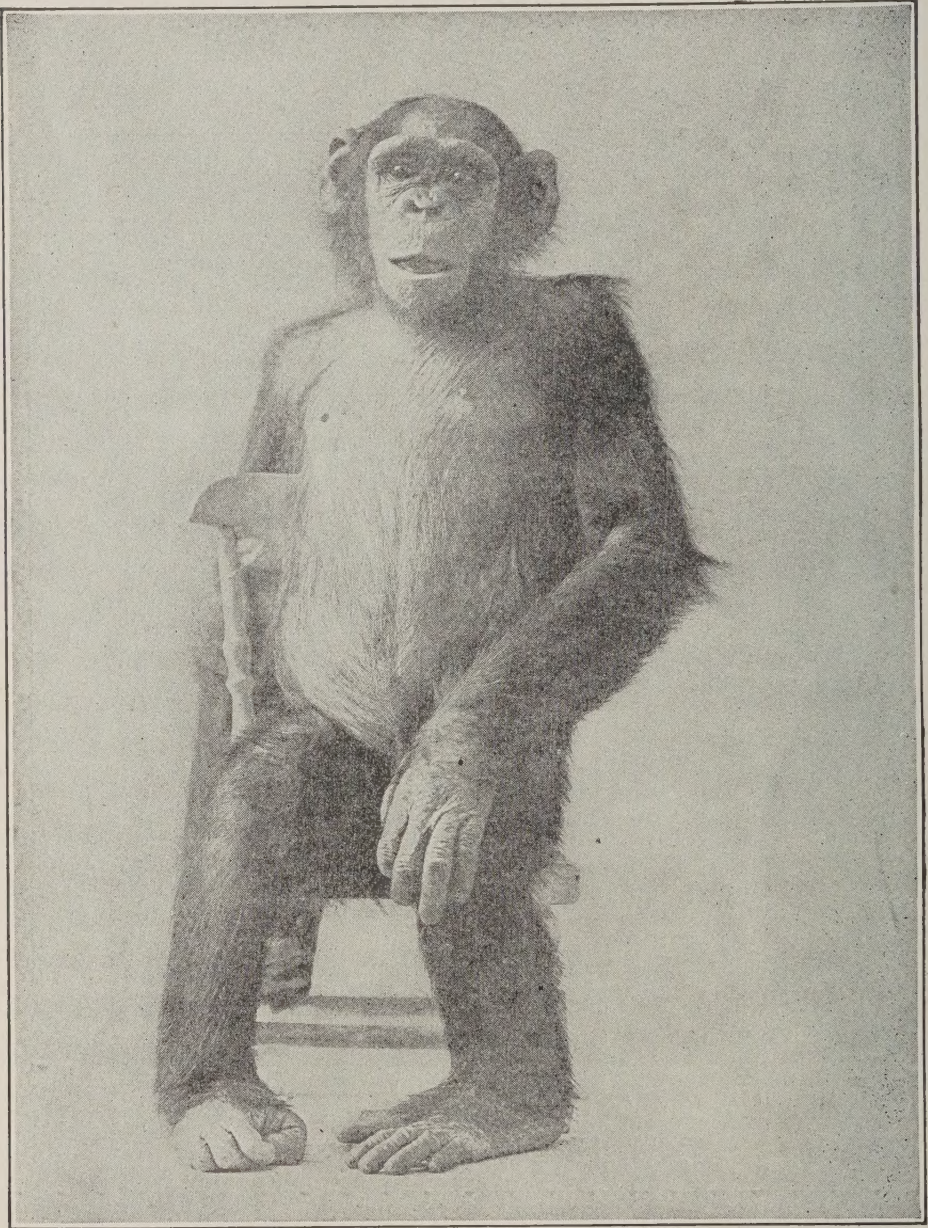


FIG. 22.—Chimpanzee, *Pan pygmæus*, western and central equatorial Africa. (From Lull, photograph from the New York Zoölogical Society.)

Another question almost certain to be asked is, "How long has mankind been on earth?" Qualified paleontologists and

anthropologists agree on the fact that man has existed throughout the entire Pleistocene period and possibly to a very small

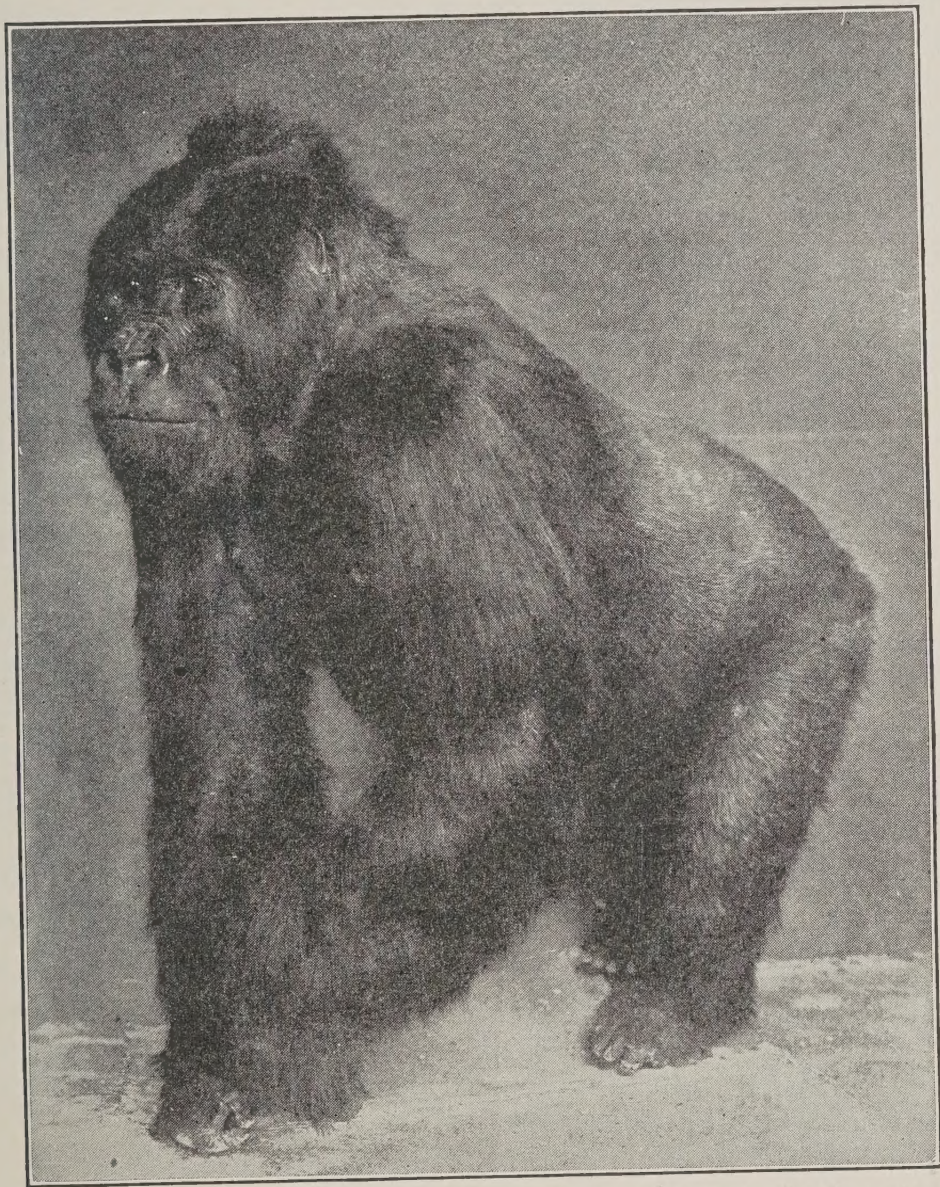


FIG. 23.—Gorilla, *Gorilla gorilla*. Mounted specimen in the American Museum of Natural History. (From Lull.)

extent into the Pliocene. The beginning of the Pleistocene period is usually placed by paleontologists at about five hundred thousand years ago. (See Chapter XV on The Paleontological Record.)

The evolution of the human body during the past twenty thousand years has probably been very slight. Man's evolution during this time has been mostly mental and social, resulting from the accumulation of experiences (skills, traditions, facts, and ideas) and the transmission of these from generation to generation through social rather than biological heredity. Although there has been relatively little change in physical structure during this time and although vast advances have been made through mental and social evolution, there is no reason to assume that physical evolution is not going steadily on. Twenty thousand years is a very short time in the life of most species. If there were as much change as one-half of one per cent each thousand years, it would take only two hundred thousand years to have a totally new species differing in every detail; but this would mean a change of only ten per cent in twenty thousand years, and such a change would be scarcely noticeable. *It is quite well known that few species have changed completely in two hundred thousand years; therefore, it is not strange that man's physical body has not changed more rapidly. The outstanding fact is not that man's body has changed so slowly, but that he has changed so rapidly mentally and socially through a kind of evolution quite different from biological change.*

This chapter should not be brought to a close without mentioning the fact that the word Primates has a double significance. Not only are the members of this order the foremost animals in evolutionary development, so far as the central nervous system is concerned, but they are also the "first" in the sense of being, in the main, primitive and generalized so far as many other fundamental traits are concerned.

The human being, as stated in another chapter (Chap. XII) has primitive teeth, primitive feet, primitive hands, a primitive or generalized digestive system, a degenerated sense of smell, and the like. In fact, it would be difficult to find anything except the brain and central nervous system, that is highly developed. It is in his *conscious control* of certain of his bodily organs,—especially the hands and the vocal organs,—that man

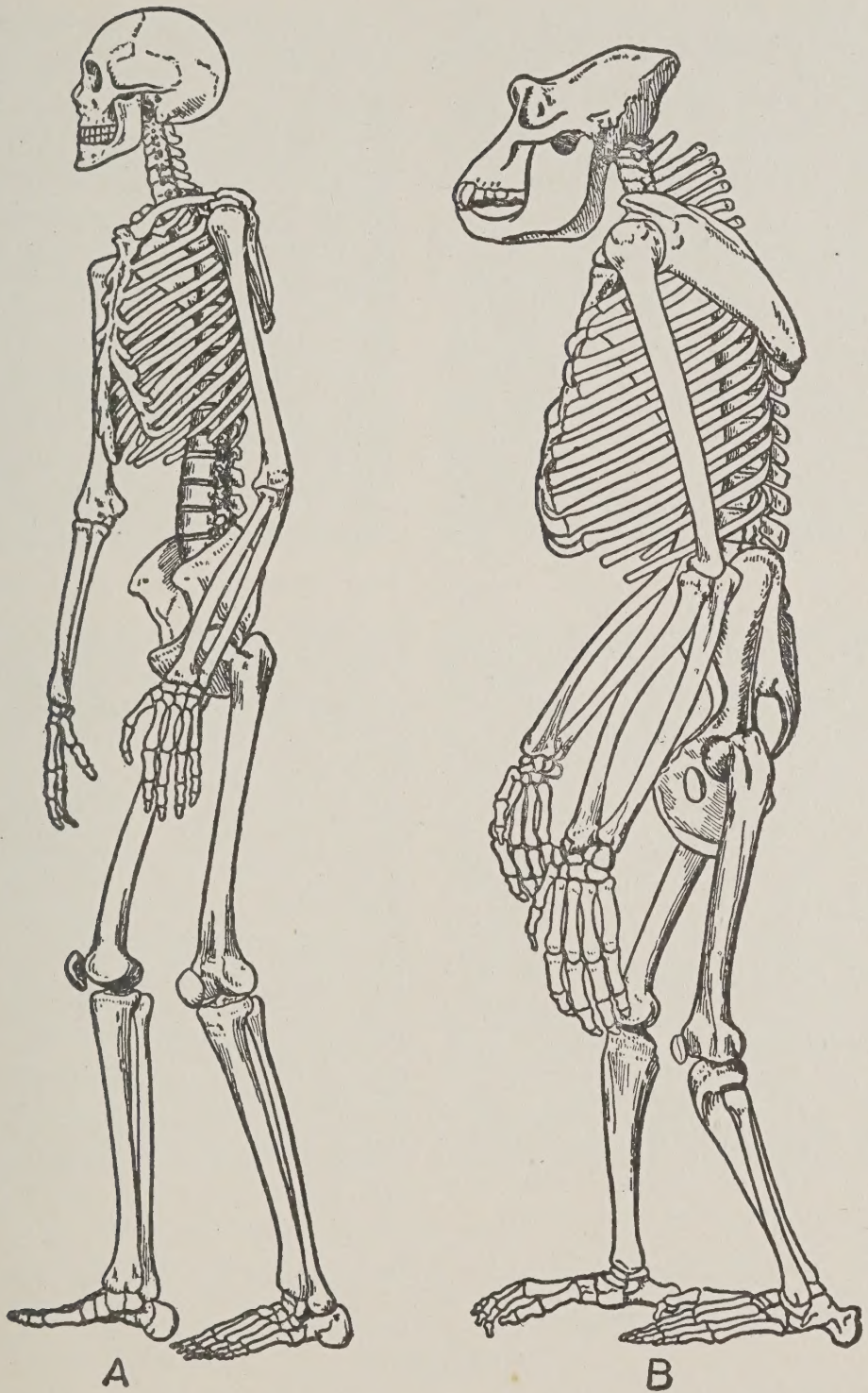


FIG. 24.—Skeleton of man and gorilla. (From Lull.)

is most clearly differentiated from the lower animals, and this control is made possible by this highly developed nervous system.

Those who first gave the name Primates to this order very probably did not realize that the name has a double significance.

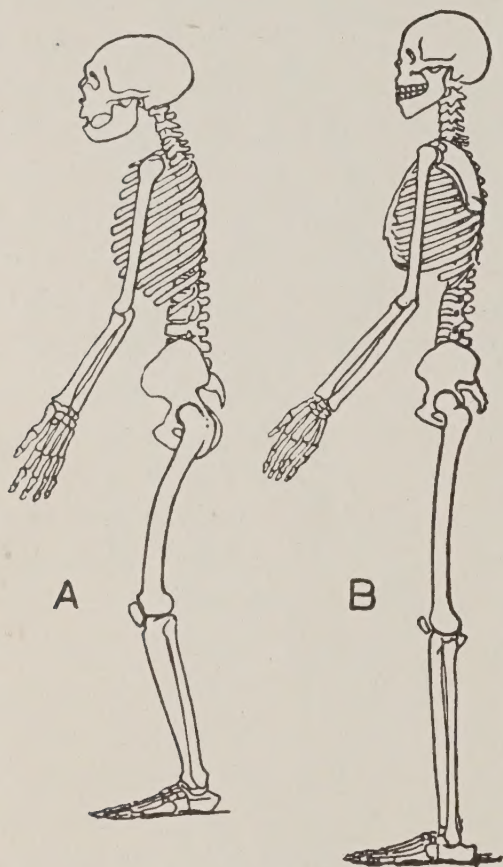


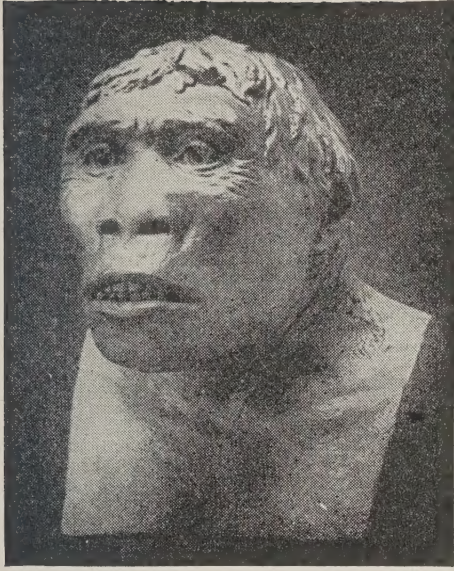
FIG. 25.—Skeleton of Neanderthal man. A, *Homo neanderthalensis*, compared with that of a living native Australian, B, *Homo sapiens*, the latter the lowest existing race. (From Lull, after Woodward.)

Originally it was meant to give the monkeys, apes, and man particularly, a high place in the animal kingdom; but it is now known that probably only in brain power is mankind above the other animals. Our hands and other organs or senses may be highly trained and educated, but this training is due not so much to the organs or senses immediately concerned as to the control over these organs or senses by the higher nerve centers of the brain. After all, it is in the development of the brain that educators are primarily interested. *It is, and probably always will be, necessary to keep the other organs of the body in sound condition; but it would seem that the chief reason for so doing is to make possible favorable conditions under which the brain may work.* We should

care for the physical in order to attain the mental, for man's field is primarily the mental.

QUESTIONS

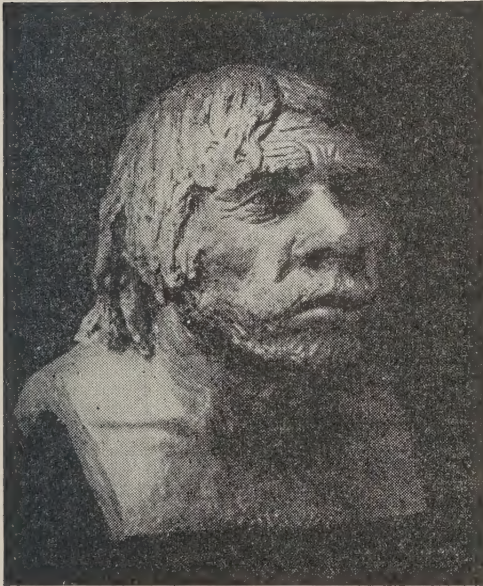
1. Why do you think that most of the primates are to be found in the tropics and sub-tropics?



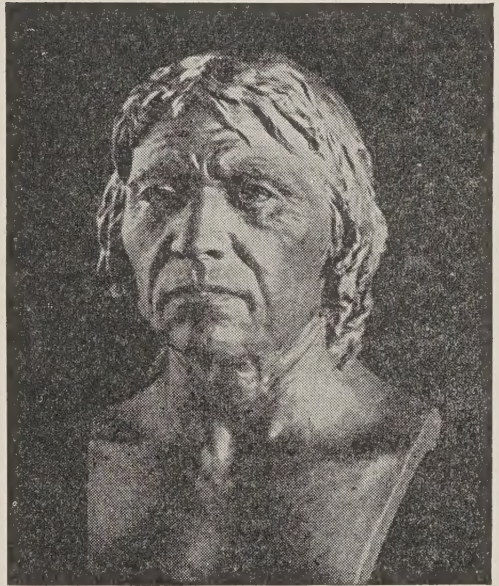
A



B



C



D

FIG. 26.—Restoration of prehistoric men, after models by J. H. McGregor. A, *Pithecanthropus erectus*, the ape-man of Java; B, *Eoanthropus dawsoni*, the Pittdown man; C, *Homo neanderthalensis*, the Neanderthal man; D, *Homo sapiens*, the Cro-magnon man. (From Lull, courtesy of Professor McGregor.)

2. What reasons can you give for the fact that the most advanced races of mankind are not found in the tropics?

3. Is it probable that the higher anthropoids may ever evolve into species with as much mental development as man? Why or why not?

4. Can you think of any reason why man and the higher apes should have much in common, other than that they have had a common ancestor? If so, what?

5. If the first representatives of *Homo sapiens* were of a certain color how did the other races of other colors come into being?

6. Why do you think it is an advantage that man remains primitive (generalized) in most of his physical traits?

7. At what age do you think it wise for persons to become acquainted with the facts and theories presented in this chapter? Would it be well, if possible, to withhold a knowledge of these facts and theories from some people? If so, from what groups, and why?

CHAPTER XII

MAN AS AN ANIMAL

How he differs from other animals—How he is similar—Bodily structures and functions of man which are inferior to similar traits in other animals—Structures and functions of man which are superior to similar traits in all other animals—Is man, in the main, a generalized or a highly specialized animal in his structures and functions?

It is the purpose of this chapter to point out the relation of the structure and function of the parts, tissues, and organs of the human body to the structures and functions of corresponding parts, tissues, and organs in other forms of life. Since an enormous amount of research has been done in this field and since many misleading statements have been made about the human body, it will be well to summarize the well-established and essential facts and principles in this field.

One of the obviously false statements is that the human being in every way is superior to all other animals. A little investigation proves that such a statement is on a par with the naïve belief of days gone by that kings were perfect specimens in every way—physically, mentally, and morally.

That the human being is not so highly developed in some of the functions of his body as are some of the lower animals is easily shown when we compare man's sense of smell with that of the dog. Anyone familiar with the fox, wolf, and dog family, *Canidæ*, knows that these animals can trace a rabbit by the scent of its tracks. No human being could trace a rabbit or any animal by the scent of its tracks alone. The dog family, with few exceptions, has the sense of smell developed far beyond that of man. Some of the insects, too, such as moths, show a far higher development of the sense of smell than the human being.

The eyes of the eagle and many other birds are far keener than

those of man. The eagle soaring a quarter or a half mile high appears to have little difficulty in locating a rabbit running about on the earth's surface. Under like conditions the human eye could see equally clearly an object no smaller than a sheep. There are hundreds and perhaps thousands of animals that have keener eyesight than that possessed by mankind.

The sense of hearing seems to be much better developed in some of the higher animals than in man. This statement is difficult to prove, but careful observation by zoölogists, naturalists, and hunters goes to show that in the human being the ability to hear is far below that of the deer, the squirrel, the duck, and a number of other mammals and birds.

The development of the sense of taste is difficult to test; so a generalization is practically impossible.

The various sense-organs involved in touch might on first thought be considered more highly developed in the human being than in any other animal; yet this is very doubtful when we consider the delicate sensitiveness of some of the membranes of the bat family, animals which seem to make their way through the air as much by feeling as by sight. The beaks of a number of birds are fitted to probe in soft mud for worms and grubs and are extremely sensitive to touch—for example, those of the woodcock and the Wilson (Jack) snipe.

It is highly probable that some of the lower animals may have certain sense-organs developed far beyond our power to comprehend. For example, it is possible that insects detect sound vibrations far higher than the human range, or even slightly lower.

If we compare the foot of man with that of the horse, the deer, the dog, and the bear, we find that the human foot is not by any means the acme of evolution. Although other animals, such as the bear, have feet that are just as primitive and clumsy as man's, no mammal has a foot more primitive.

Those who have given the matter careful study assert that the most primitive of mammalian feet is that of the "plantigrade" type, in which the heel as well as the toes touch the ground when the animal is walking. No special or peculiar func-

tions are performed by these appendages: consequently the foot is still generalized in structure. In animals possessing the plantigrade foot, great speed is not essential to the life of the species, nor is it necessary that they be able to steal up quietly on their prey or to climb trees.

In the "digitigrade" type of foot, the heel is usually quite far removed from the ground, in fact never touching it except possi-

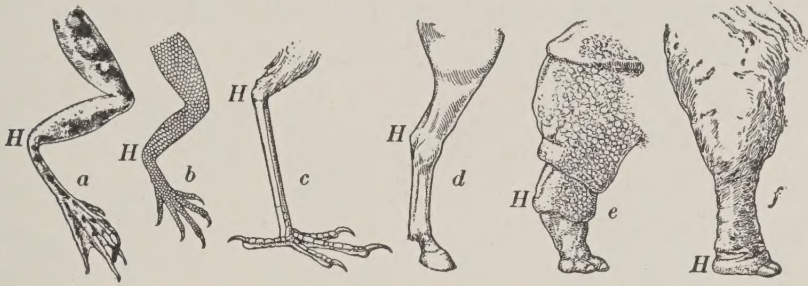


FIG. 27.—*Homology in hind legs of vertebrates.* The hind legs of all four-footed animals and the legs of birds correspond to a large degree. In spite of the many differences between them we can easily find the resemblance in the legs and feet of the frog, *a*; the lizard, *b*; the bird, *c*; the horse, *d*; the rhinoceros, *e*; and the elephant, *f*. *H* is the heel in each case. (From Gruenberg's *Biology and Human Life*, by permission of Ginn and Company, publishers.)

bly when the animal is resting or progressing very slowly. Good examples of this type of foot are found in the dog and cat families, the members of which far more than the members of the bear family rely upon speed for their food and protection and, in the case of the cat family, on stealthiness of movement. These animals walk and run upon the toes, as do all mammals that attain great speed. The members of the deer family also attain great speed. They have highly specialized feet called "unguligrade." Only two of the five digits are functional to any great extent, but these are modified in the extreme. In the deer family, as in all the hoofed mammals, the toe-nails have been greatly enlarged and specialized and form the hoof. Man has no chance in a foot race with such animals.

The horse family, *Equidæ*, consisting of true horses, zebras, jacks, burros (donkeys), and the hybrid cross, the mule, have the unguligrade foot specialized even more than that of the deer.

In the *Equidæ* only one toe is functional, the toe-nail of the middle toe forming the hoof. All the other toe bones are either lost or vestigial, that is, only remnants of the original toes are found in the species living to-day. Two vestigial toe bones can be found internally on each leg of the horse. The heel of the hind foot is to be found nearly two feet above ground,—the protruding back of the horse's "hock" joint.

One may truthfully say that the foot of the human being is many million years behind that of the horse. In fact, the human

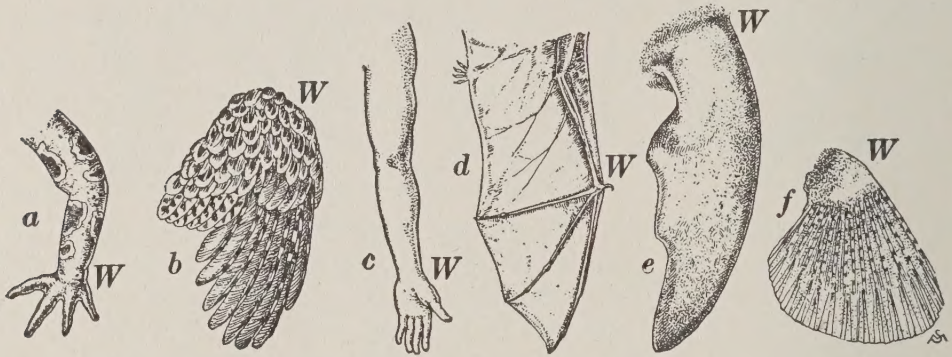


FIG. 28.—*Anterior limbs of vertebrates.* The limbs of the different classes of backboned animals are so distinct that most people never discover that they are all different forms of the same organ. W, the wrist: *a*, frog; *b*, partridge; *c*, man; *d*, bat; *e*, dolphin; *f*, blackfish. (From Gruenberg's *Biology and Human Life*, by permission of Ginn and Company, publishers.)

foot is very generalized and primitive, retaining the pentadactyl or five-toed condition found in the amphibian and reptilian classes.

We often think of the human hand as highly evolved and specialized. True, the human brain directs the hand to do many marvelous things, but the hand still retains the generalized structures found in primitive vertebrates, such as toads, frogs, lizards, and turtles. The fact that the hand of man can be set to such varied tasks indicates both that it retains largely its primitive structural traits, and that the directing brain is highly developed. The bird's front feet, called wings, are far more highly specialized than are our hands, since they accomplish just one thing exceedingly well, flight. Naturally they have the corresponding

specialized structures, having lost certain of the bones of the hand and having other bones fused together in order to stiffen and strengthen the wing.

The teeth of man are far from being specialized, compared, for example, with those of the horse or beaver. In man's mouth are to be found all types of teeth—incisors, canines, premolars, and molars, thus enabling him to eat a great variety of food, from meat to coarse herbs. Man, being both carnivorous and herbiv-

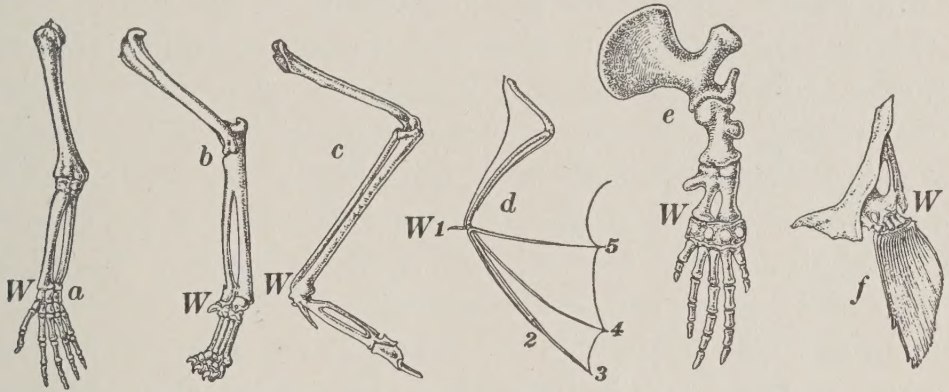


FIG. 29.—Homologies in the skeletons of vertebrates. In spite of the different appearance and different functions of the limbs of backboned animals the supporting structures have the same general plan. *W*, the wrist bones: *a*, man; *b*, lion; *c*, vulture; *d*, bat; *e*, whale; *f*, halibut. (From Gruenberg's *Biology and Human Life*, by permission of Ginn and Company, publishers.)

orous, has teeth to handle both kinds of food, while the horse, beaver, cow, mouse, rat, prairie dog, and rabbit, are strictly herbivorous and have specialized teeth for gnawing and grinding.

The digestive system of the human being is also generalized. This would quite naturally be so since the teeth are generalized and it would be very peculiar, indeed, if the teeth and the digestive organs did not complement each other. Our food is extremely varied—even in wild tribes whenever a great variety of food is available. In fact, very few animals have so wide a variety for their diet. On the other hand, many animals, such as cows, beavers, eagles, have very highly evolved and specialized digestive organs, highly fitted for only a narrow range of food materials.

Man's legs are not the most highly evolved legs in existence. Man cannot run so fast as the rabbit, jump so far as the kangaroo, support so great a weight as the ox, climb trees so rapidly as the squirrel, dig holes so quickly as the badger, nor steal upon his prey so quietly as the cat. In fact the legs of the human being can do none of these things extremely well, but are still generalized to such an extent that all of the above functions can be done fairly well.

In a study of all of the parts or organs of the human body it is impossible to find any structure or function more highly developed than the corresponding structure or function in some other animal, but for *one outstanding exception*. Man's central nervous system, especially the brain, is superior to that of all other species. The highly evolved nervous system is the part of his anatomy that sets him off from all the rest. His superiority and control of other species is based on this alone. The human hand is very nimble and versatile, but not more so than that of the apes might be if they had the highly specialized brain to direct it.

It was once thought that man had the largest brain of all animals or at least the largest amount of gray matter in proportion to the rest of the body. We know now that, although this is true in comparison with most of the vertebrates, the larger whales and the elephants have larger brains than man and some birds have a larger proportion of gray matter to total brain weight than the human species. Man's superiority therefore rests not on quantity alone but on quality or functional capacity.

It is reasonable to suppose that the highly specialized functions of the central nervous system of man are indicative of highly specialized structures. The specialization is really in the vast number of *connections* that are possible among the various parts of the nervous system. There is definite structural evidence of the superiority of man's brain in the fact that there is a vastly greater number of direct nerve-connections between the higher centers of the cortex and (ultimately) the muscles. This is demonstrable by comparing cross-sections of the spinal cord that

reveal the relative magnitude of the bundles of fibers that connect the higher with the lower nerve centers. This seems to provide a *structural* basis for the most important *functional* superiority of *Homo*, namely, a high degree of *conscious control of movement* making possible (1) the use of tools and (2) articulate language.

It is quite generally agreed that the so-called "power of thought" is inextricably connected with the possibility of fine

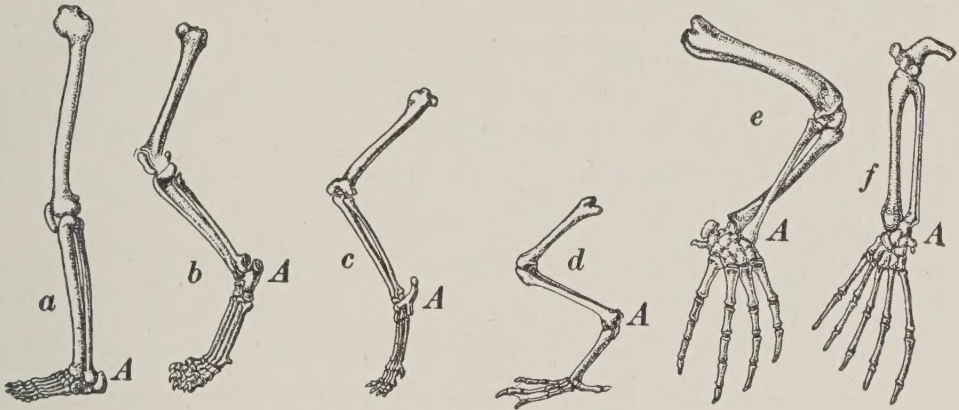


FIG. 30.—*Homologies in the bones of the hind leg.* Walking, crawling, swimming, loping—all the various kinds of locomotion found among backbone animals—are carried on by organs having the same fundamental structure. A, ankle bones: a, man; b, lion; c, wolf; d, duck; e, crocodile; f, seal. (From Gruenberg's *Biology and Human Life*, by permission of Ginn and Company, publishers.)

motor adjustments. Indeed the suggestion has been made that a high degree of what the psychologists measure as "intelligence" may be due in part to unusual ability to move the eyes rapidly in reading. Whether this be specifically true or not, it is reasonable to infer that the *conscious* control of fine muscular adjustments of some sort is closely associated with the ability to think.

Man's ability *consciously* to direct his movements is the basis of *learning*, in fact the basis of almost all phases of civilization. Many other animals direct their own movements but without so high a degree of conscious and "intelligent" control. Learning in man is to a large degree a process of changing behavior, of changing activity of some sort.

It must not be inferred, however, that man's superior mental endowment gives him an undisputed advantage in the struggle for mastery of the earth. Professor W. M. Wheeler, an eminent entomologist, has said this is the age of man and of insects. At present, in most places of the earth, man is winning the battle, but in Africa enormous areas are uninhabitable by civilized man because of the abundant disease-producing insects. Even in the most civilized countries part and sometimes all of the crops are destroyed by insect pests.

We often think of man as being an abundant species on earth and in a sense he is, but compared to certain species of insects, his ratio is but one to ten thousand or even less. If the insects dominate, it will be due largely to numbers; if man continues to dominate it will be due to his intelligence.

Even though mankind is organically inferior (except in structure and function of the nervous system) to other animal species, yet his mental superiority is of more value than all the other superiorities combined. Any person would rather be a human being for a year than a cow or any other animal for a millennium, even though the latter may have more highly specialized teeth, hoofs, sense-organs, or other parts of the body.

The superiority of the nervous system of man has been the deciding factor in many a battle with other animals. This was true thousands of years ago as it is now. Because of man's ability to use weapons, (clubs, rocks, traps, bow and arrows), other animals served as food for him more often than, because of their strength, speed, or ferocity, he served as food for them.

It appears that up to the time of the Jurassic age, about twenty-five million years ago, evolution was to a large extent toward increased size. In that age, bigness rather than mental alertness or adaptability was the primary factor in survival. During that age there were giant herbivorous and carnivorous reptiles, sometimes weighing as much as forty tons and attaining a length of eighty feet. The brains of these animals were exceedingly small, seldom weighing more than a few ounces. With limited intelligence, they were unable to adjust to new conditions

and new kinds of food. When climatic conditions changed, they were unable to make a corresponding adjustment or to migrate speedily over small barriers to other places; thus they perished.

Paleontologists generally agree that large size represents a high degree of specialization and that whenever a species becomes large, it is soon—speaking in terms of geological time—likely to become extinct. If one traces the racial history of animals of large size, one will find that this is nearly always true. Therefore, in all probability, the days of the elephant and the large whales are numbered.

In the chapter on classification it was stated that human beings, apes, and monkeys are classed as Primates, because they are much alike and represent the highest form of animal life. As was pointed out, however, the name has a double significance in that man is primitive, having very generalized structures in nearly every part of his body, except for his highly developed nervous system. Because he is both generalized structurally and intelligent functionally, he can adjust himself to a wide variety of environments. Whenever an animal is found with highly specialized structures, it means that it is adapted to a highly specialized environment, usually with a very limited range.

Over a long period of time, the animals that have retained generalized traits have survived, while those that were highly specialized have failed. *Specialization to a high degree seems to be a good thing for the individual but a most dangerous thing for the race.* It remains yet to be seen whether man's high degree of specialization of the nervous system will be a handicap to the human species, as many people believe may be the case.

If the various organs of the body are examined, we find that both man and the apes have the same number and kind located in the same general area. Even the teeth are of the same number and agree exactly as to the number of each kind. Both the human being and the chimpanzee have eight incisors, four canines, eight premolars, and twelve molars. The vestigial structures of both (the vermiform appendix, nictitating membrane, the pin-eal eye, ear-muscles, etc.) are identical, differing only in degree.

In fact the chimpanzee, and the three other anthropoid apes—gorilla, orang-utan, and gibbon,—*differ structurally from man only in degree.*

Not only do the anthropoid apes and the tailed monkeys have structures similar to the human being, but all the other *Primates* do also, some differing from man more in degree than others. Nor is the similarity of structure confined to the order *Primates* but is to be found throughout the whole class *Mammalia*. Great similarity to man in structure is found throughout the whole phylum *Chordata*. One is truly amazed to find that anatomically the frog, the lizard, and the robin have so many points in common with man.

The figure showing the front limb of a number of widely different species illustrates the great similarity of corresponding parts. It will be seen that the more distantly related the species, the more unlike are the parts and that the reverse is equally true. The close duplication in structure in thousands of parts in both man and the lower animals shows a kinship, remote but real.

The reader, if he observes closely, will already have solved many minor problems for himself in the light of this knowledge of the structural similarity of man and the lower animals, particularly of the mammals.

Two important additional generalizations can be made concerning food and concerning exercise. If one observes the kind of food eaten by animals having teeth similar to those of man, one will get some reliable suggestions as to what man can properly eat. All animals having four distinct kinds of teeth—inisors, canines, premolars, and molars—have a mixed diet if possible, and are capable of digesting and thriving on a diet composed partially of meat. Since the teeth adapted to the cutting of meat are few and poorly developed in those animals with a variety of kinds of teeth, it seems obvious that the proportion of meat food should be small. Since only four of the thirty-two teeth in man are distinctly carnivorous in nature and since they are poorly developed, it would seem safe to infer that only a small proportion of man's diet should be carnivorous.

We find that the apes have an extraordinary muscular development, due doubtless to their method of procuring food and defending their young and themselves. The large proportion of muscle in the human body, 43 per cent, is partially due to the continued inheritance of structures long after they cease to be of great use. A safe generalization to make here is that if we would keep our bodies healthy, we, too, must exercise a great deal. No part of the body can be allowed to atrophy without serious menace to health. *Presumably it takes as many thousands of years to lose an organ as it did to develop it, and therefore the human race will probably need to exercise regularly scores of generations after machines are doing nearly all of the physical labor essential to supply the necessities of life.*

Man is physically an animal, and we must start with that fact as a basis if we would understand him and his offspring, the child. *The child is even more of an animal than the adult, since in every way he exhibits the more general traits of his race.* Man is the ruler of his universe chiefly because of a highly evolved nervous system and not because of strength or speed.

QUESTIONS

1. Why do you think that nearly everybody believes that man is superior to all the other animals in almost every way?
2. Would man as a race be better off if he had the most highly developed organs and traits in all respects, as well as the most highly developed central nervous system?
3. Why do you think man retained the plantigrade type of foot?
4. If biological specialization to a high degree is a dangerous thing for the race, does it naturally follow that high specialization in professions and trades is also a dangerous thing for the race?
5. Why do you think that the wealthiest people on the average have the fewest children?
6. Why do you think that the educated people on the average have fewer children than the semi-educated or the illiterate?
7. Do you think the child is more nearly like the higher mammals than is the adult? Why or why not?
8. Physically is the child, considered as a whole, more highly or less highly specialized than the adult? What evidence do you have?
9. Give reasons why the child should have more exercise than the adult.

10. Can you give biological reasons why the child has difficulty in learning how to write?

11. Do you think you would have profited if, as a child in the lower grades, you could have been informed of some of the facts in this chapter? In the upper grades? If so, what facts and how should they have been presented to help you the most?

CHAPTER XIII

INSTINCTS IN THE LOWER ANIMALS AND IN MAN

Do animals have instincts?—Some fundamental instincts or tendencies in the animals—Instincts or tendencies in children—The warping of human instincts—Should any of the instincts of children and adults be suppressed?

The term "instinct" has been used by both biologists and psychologists to designate inherited types or patterns of behavior. It is a fact of common observation that many of the lower animals immediately or very soon after coming into the world make very definite movements. Inasmuch as these movements are obviously not learned through experience, it has been assumed that the animals are born with certain nerve-connections already fixed and ready to operate when the appropriate conditions arise. In some cases, these behavior patterns are relatively simple, involving only a single set of responses to a very definite stimulation, as when the chick begins to pick up grains of food or grit.

Other behavior patterns are much more elaborate, as when a bird, even if it has never had a chance to learn the operation from other birds, will at a certain time build a nest in which to lay its eggs, a nest which is essentially similar to those which all birds of the same species would build under similar conditions. In short, among the lower forms of animal life, what the animal does, how it behaves, seems to be very strongly determined by connections in the nervous system which have been inherited in the same sense that other physical characters are inherited.

It is known, however, that the higher animals especially, and some of the lower animals as well, can learn through experience to make movements that are not provided for by the inherited

mechanisms. A dog may be taught to respond in very definite ways to commands and other stimuli that would not lead to the same movement in other dogs without similar training. The horse and the ox can also learn new kinds of behavior through experience and especially through training. A starfish can be taught after hundreds of "trials," to raise one particular arm of the usual five found on such animals. That which is learned after long effort is however lost in a very few days if the starfish is not continually "trained."

It has even been proved that organisms still lower than the starfish can be led to vary their behavior from the inherited patterns, at least within narrow limits. The possibilities of such learning, in general, increase as one goes from the lowest to the highest forms. As one would naturally expect, the possibilities are most numerous in the primates.

In man, the possibilities of learning through experience make possible those innumerable adaptations to changing conditions which, as we have seen, have played a most important part both in his survival and in his ability to dominate the lower forms of life. (See Chapter VII.)

The question arises, Do instincts (definite behavior patterns fixed by heredity) play a significant rôle in human life to-day? It seems only reasonable to assume that, if instincts are so important in the lower forms of life, they are also probably present (at least possibly present) in the higher mammals, including man, since the mammals including man are the descendants of lower forms of life.

Let us start with some of the most common and fundamental traits of the lower animals which have hitherto been called instincts. Perhaps nest-building as exhibited by most species of birds is as clear-cut an example as can be found. It is well-known that a young robin can build her nest the first time as well as the last time, and there is not the slightest evidence that she watches any other robin or in any other way *learns* how to build the nest. She "knows how" without learning, from the very beginning of her nest-building period of life.

Self-defense also seems to be a well-grounded instinct. Young golden eagles in a nest high on the side of a cliff attempt through definite movements to defend themselves the very first time danger approaches. It is quite certain that in most cases, if not in every case, they have had no chance to learn how to protect themselves. They "know how" with their very first experience.

In many species the parents seem instinctively to protect their young. They may even risk their own lives at the very first experience of danger in the young. A hen stoutly defends her young chicks at the risk of being trampled upon by a larger animal or even at the risk of death. This occurs not only if the hen has been hatched and brooded in the normal way, but also if she has been hatched in an incubator, has been "brought up" in a brooder, and has never seen another hen with chicks in danger.

Animals "know how" to reproduce their kind when they reach the proper physiological stage of maturity. They do not need to observe how or in other ways learn how.

In human beings it is generally agreed by most students of the problem that there are a very few types of behavior that can be properly classed as instinctive in the true sense; other types probably do not represent behavior-patterns *completely* formed at birth, but need some experience or learning to perfect them; still others represent only the vestiges, so to speak, of original behavior-patterns.

In the first group can certainly be placed the earliest movements for taking food and clutching; in the second group, reproduction, self-defense, and defense of young; in the third group can be more properly placed what were once called the "instincts" of play, imitation, curiosity, love, hate, and the like. It seems altogether reasonable to suppose that a child does not love, hate, imitate, or pry into things because he inherited the underlying nerve-connections as fully fledged behavior-patterns. Probably something innate or inborn lies back of such action, but it is better to think of the inborn elements as *general tendencies* rather than as specific and highly organized instincts,

and the definite forms which the behavior takes on as due largely to experience (learning, observation, training).

An illustration of a clearly instinctive *tendency* to defend one's offspring came to my attention recently. A woman with two children was crossing the street when one of the children was struck by an automobile carelessly driven. Just before the child was struck the mother grasped for the child in spite of the danger to which she was exposing herself. Only after the wounds of the child had been dressed and he was on the road to recovery did the woman realize that she too had been struck and considerably bruised by the car.

Now it seems that three possible reasons may be advanced to explain the attempt of the mother to save her child. First, one may maintain that the impulse was entirely instinctive; second, if she had had time to think, one could maintain that she would deliberately and willingly have risked her life; and third, if she had met several situations of this sort before, one could maintain that the response, once learned, had become through repetition an automatic learned response, or a habit. In this case, however, it is doubtful that the mother had time to think and then act; rather she acted first and then thought; nor is it likely that this situation occurs often enough in any one life to make the response a habit. The operation of an instinctive tendency or impulse to defend or protect the young seems to be the only possible explanation.

It was once commonly believed that, because instinctive behavior is definitely fixed in the animal's make-up, it cannot be altered. Such an assumption is unjustified. We have already noted the fact that even the lower animals can learn new responses under certain conditions within a relatively small range. To learn means to modify instinctive behavior or tendencies to behavior. The one animal that can greatly alter instinctive tendencies is man. *Man is preëminently the instinct-modifying animal*, which expressed in another way means that through experience he can learn to overcome in some measure, at least, the "inner urges."

Under present-day conditions the instinctive tendency toward physical self-defense is very seldom called into play during the adult lifetime of most people; consequently it may become very sluggish or almost entirely inactive. The instinctive urge for the propagation of the species, while one of the most imperious of all instincts, has been brought under a very marked degree of social control. One of the most important problems of civilization is to adjust the demands of our instinctive urges with the social and economic demands of the day, particularly as to reproduction.

The question naturally arises whether we should completely suppress any of our instinctive tendencies and particularly whether they should be suppressed in children. A very general answer is that we should not be ashamed of any of our instincts, since they were found necessary by our ancestors in order to defend and continue the species. However, the suppression of them seems often to be necessary for almost everybody, including children, although not in most cases so necessary for them as for adults.

Since there is no general agreement among biologists concerning instincts, extreme and positive statements on this topic would be most misleading. It will be safe to assume, however, that if instincts do not exist completely formed in the individual, there are at least powerful inner urges or tendencies that are inherited and that must be reckoned with. In fact some of the most troublesome educational problems center around these "instincts" or "tendencies" or "inner urges." To know how best to control them would indeed solve many of our educational problems.

QUESTIONS

1. Is it correct to say that "instinct" is inherited habit?
2. Is it easier to develop traits in children that are more or less instinctive or traits that are wholly "acquired" during their lifetime?
3. How nearly correct is it to say that a good teacher knows what to do "instinctively"?
4. Are the "instincts" of children or of adults more nearly like those exhibited by the animals?

5. Is civilization in the future likely to interfere more or less with our instinctive urges than at the present time?
6. Do you think that successful teaching is to a large degree the development and training of the instinctive urges of children?
7. Would mankind be better off if he had fewer instinctive urges? Why or why not?
8. Would the child be easier to teach if he had few instinctive urges?

CHAPTER XIV

DEGENERATION AND PARASITISM

Inactivity and parasitism as the chief causes for degeneration in plants, in animals, and in man—The origin of parasites—Degrees of parasitism—Life cycles of several important parasites subsisting on man and domesticated species.

Big fleas have little fleas
On their backs to bite 'em;
And little fleas have lesser fleas,
And so *ad infinitum*.

It is literally true that everything has its parasites, either internal or external, temporary or permanent. At least, everything, except the microorganisms, that has been examined carefully thus far has been found to be parasitized to a greater or less degree.

Animals which habitually feed on raw flesh are almost certain to be heavily parasitized. Even animals which feed on grass or vegetable foods are quite sure to harbor parasites of some kind somewhere in the body. Since most human beings eat a certain amount of uncooked food, they, too, are likely to be somewhat infected or infested. In countries where the laws of sanitation are little known or practiced, the incidence of parasitism in human beings is very high, perhaps as high as in the wild and domesticated animals of that region.

Children of school age are probably more often parasitized than adults, because habits of cleanliness are not easy to establish, and in mankind cleanliness is apparently not instinctive, as in some of the lower animals, but must be learned through experience (discipline, training). The close association which many children have with pets, particularly cats and dogs, only adds to the chance of acquiring parasites.

If we define a parasite as something which lives on or in

another animal or plant without returning the equivalent, we probably have a definition as workable as any that can be made. This definition allows for a great variation in kinds of parasites and degrees of parasitism.

Perhaps the most outstanding fact about a parasite is the almost certain degeneration of some of the organs of its body. This degeneration progresses directly in proportion to the increasing permanency of the parasitism. In the case of the mosquito, which spends but a very few minutes of its lifetime sucking blood from its host, we can observe little, if any, degeneration. On the other hand, a permanent parasite such as the beef tapeworm in man is extremely degenerate. This tapeworm, like almost all tapeworms in both man and the lower animals, is so degenerate that in a mature segment very little else than eggs can be found.

Since all the human tapeworms are literally surrounded by food in the intestines, they have no use for a digestive system. Consequently they have so degenerated that there is no trace of any part of the digestive organs. They have no need for eyes or eye spots, and close observation of their anatomy shows that such organs are entirely lacking. Their power of movement is very feeble, also, since little motor activity is necessary. In fact, the tapeworm is so dependent on its host for its food and environment that it has degenerated in almost every way, save in the size and power of the reproductive system. Throughout its entire adult life, nearly all of its energy is devoted to the production of eggs. An extremely large number of eggs must be produced because of the small chance of their finding the right intermediate host—sometimes less than one chance in a million.

Another example of extreme degeneration is found in *Sacculina*. In the larval stage this animal is a typical small, free-swimming crustacean. For a number of days it continues this free life; then it settles down upon a certain species of crab and loses its former identity completely. The head, eyes, thorax, abdomen, and legs are entirely lost. Nothing is left but a sac-like structure with root-like organs ramifying throughout the body

of the host gathering food to be brought back to produce a multitude of sacculina eggs. These eggs in turn hatch, produce free-swimming larvæ which degenerate in the adult stage until, in their turn, they are nothing but small bags containing eggs.

Although we speak of parasites as being degenerate forms in nearly every case, yet from the standpoint of the parasites themselves, they are highly evolved and successful species. After all, the only purpose of any species, except the human being (if other species may be said to have aims), is to keep its kind in existence and to spread its kind as far as possible. Parasites are wonderfully successful in maintaining and disseminating their kind. Only in the sense that they do not lead a free life can we say that they are degenerate. A tapeworm is certainly successful as a tapeworm, but not as a free-living worm. Even sacculina is successful as such but not as a free-living arthropod. *Degeneration resulting from parasitism is really specialization when viewed from the standpoint of the species concerned.*

Direct contact and struggle with the outside world for a place and for food seems to be absolutely necessary if an organism is not to lose some of the structures and functions of its body. Probably the greatest single factor in the evolution of life has been the necessary struggle of each individual of each species to maintain its existence. Conversely, however, individuals and species sometimes fail in the struggle for a place because the battle has been too severe. On the whole, this is a good thing, since the best adapted forms and the strongest individuals are thus preserved.

Examples of parasites are so numerous that it is impossible to pick out and discuss all the important ones. Arbitrarily we shall select a number and divide them into two groups—those that are parasitic on human beings and those that are parasitic on other species. Among the most important types parasitic for at least a part of their life cycle in or on mankind are tapeworms, ascaris, hookworm, trichina, malaria. Other important parasites of other animals and plants are dodder, sacculina, botflies, cattle ticks.

There are at least four important human tapeworms: *Tænia*

saginata, *Tænia solium*, *Diphyllbothrium latus*, and *Echinococcus granulosus*. The first three are found in the adult stage attached to the intestinal wall and the last one in the larval condition in various parts of the body including the liver, lungs, kidneys, spleen, heart, brain, membrane lining of the body cavity, and various muscles.

Tænia saginata is known as the beef tapeworm since man is infested by eating raw or rare beef harboring the larval stage called the cysticercus or bladder worm. These cysticerci, about one-third of an inch in length, are visible to the trained eye, embedded in the beef muscles. In common with some other tapeworms, the life cycle is composed of four stages—the egg, the onchosphere or six-hooked embryo, the cysticercus or bladder worm, and the adult. The eggs, usually numbered by the thousands, are found in the mature segments which break off and pass out with the fæces, often as many as a dozen a day. These proglottids may be eaten entire by the cow, or the segments may dry and break open, thus scattering the eggs widely. In the digestive system of cattle, the eggs complete their development into the six-hooked embryos; these in turn bore through the intestinal wall and lodge in the flesh, especially in the muscles of mastication. There they grow and change into cysticerci or bladder worms, often remaining for a considerable time. If the flesh of this infected animal is eaten by a human being, the cysticerci, which are practically inverted embryos,¹ change into young adults attaching themselves to the wall of the intestine by means of suckers. In no other way can man be infested by the beef tapeworm.

Near the head end or scolex, segments are budded on and thus multiply until they sometimes number as many as one thousand, with a total length of twenty feet. When the tapeworm becomes about full size, several hundred segments may be liberated each month passing out with the fæces.

Since the beef tapeworm can be taken into the human body only by eating raw or rare beef, the method of prevention is ob-

¹ Embryos with the external walls turned inward.

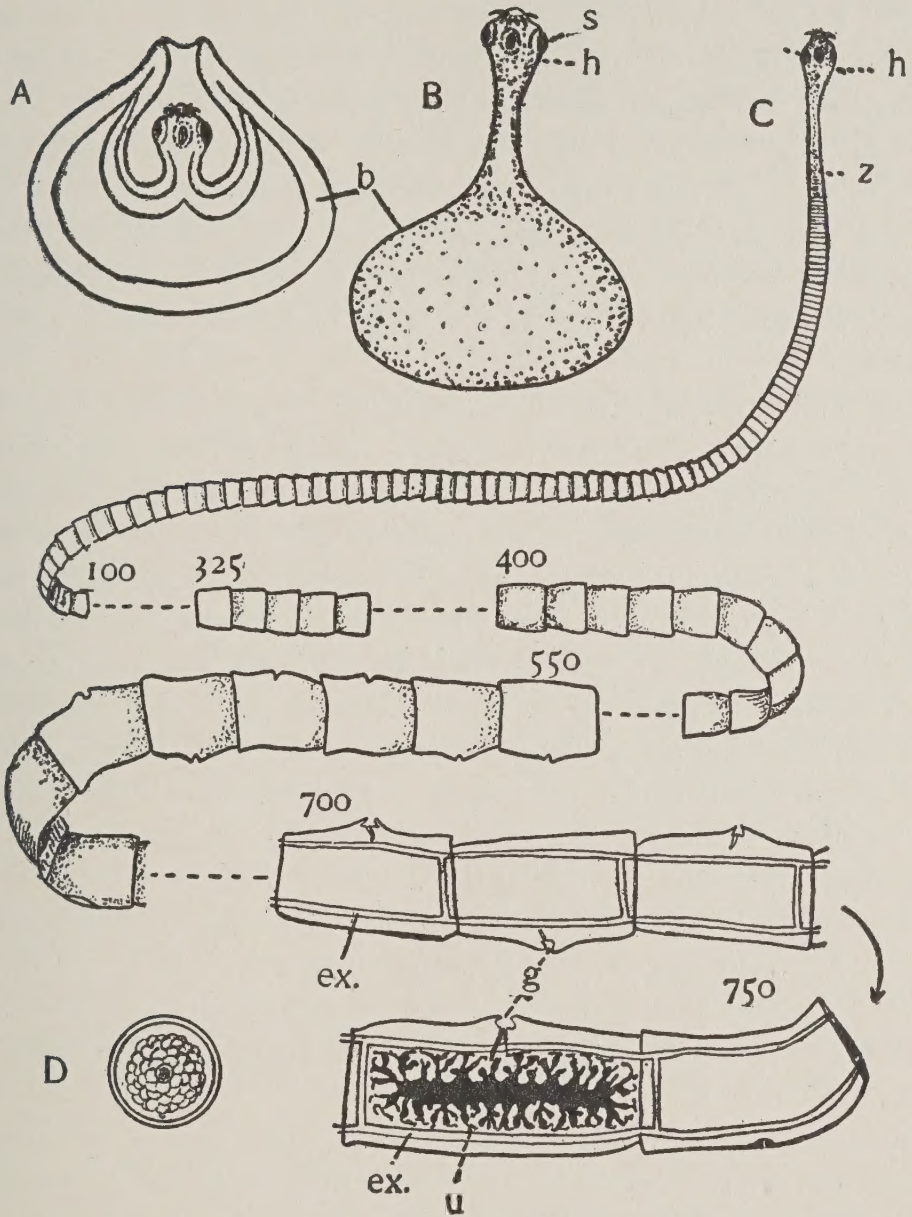


FIG. 31.—Stages in the life cycle of the tapeworm of the genus, *Taenia*. A, B, cysticercus or bladder worm stage, the latter after the scolex has been everted. C, the adult worm showing many segments, from the immature to the mature. D, the egg. s, sucker; h, scolex or "head." z, neck of head region; ex, longitudinal excretory canals with transverse connecting vessels; u, uterus; g, genital pore. (From Galloway and Welch's *Textbook of Zoölogy*, published by P. Blakiston's Son & Co. Inc., Philadelphia.)

vious, namely, to eat only well-cooked flesh. If one is infested, the cure is not a difficult one. One should refrain from eating for a day, and then take a medicine such as oil of chenopodium which will kill the worms. This drug should be followed shortly by a purgative. It is very important that the latter be taken as well as the former; otherwise the patient may be poisoned by the toxins arising from the decomposition of the worms in the intestines. Fatalities have been reported where the latter precaution was not taken.

The life cycle of the pork tapeworm, *Tænia solium*, found in raw or rare pork, is similar to that of *Tænia saginata*. The worms differ somewhat in the fact that the scolex of the latter has hooks as well as suckers and is usually smaller and shorter with shorter individual segments. Some have as many as 900 segments and attain a length of ten feet. Fortunately the danger of being infested has been greatly reduced by the excellent propaganda of the United States government about a generation ago concerning the great danger of eating raw or rare pork. Occasionally the larval form of this tapeworm is also found in man and the adult stage in the pig thus making it doubly dangerous and increasing the chance of infestation.

The fish tapeworm *Diphyllobothrium latus* is acquired by eating raw or rare fish. It is similar in the adult stage to the other two. It differs from the others structurally in that it becomes extremely long, with an authentic record of over thirty-nine feet.

Echinococcus granulosus is a somewhat rare species of human tapeworm in the United States, although common in Iceland and Australia. The adult stage is found in the intestine of the dog, where it does very little harm. The larval state found in man, however, is very serious since it grows to be very large, sometimes attaining the size of a baseball or even larger in rare instances. It is particularly serious because it often attaches itself to such organs as the liver, lungs, kidney, spleen, heart, or brain, where removal by operation is almost impossible.

The larval form of this parasite, also called hydatid, or hydatid

cyst, at first is very small, measuring about one twenty-fifth of an inch in diameter, but in about five months it attains the size of a walnut. At this stage a number of brood capsules appear on the inside of the cyst, and in turn a number of heads or scoleces appear on the inside of the capsules. Each of the scoleces will eventually develop into an adult tapeworm in the dog, if given a chance. Since there may be as many as a dozen brood capsules in one cyst and since each capsule may contain a dozen or more scoleces, it is obvious that more than a hundred heads may be produced from one cyst, making a very large foreign structure in the body.

In addition to these four tapeworms, there are several other tapeworms found in man, but they are mostly smaller and, in most cases, of much less importance.

Hookworm disease is caused by another common human parasite found in the southern part of the United States, most frequently below the frost line. It is estimated that over a million of people including both whites and negroes harbor this parasite, at least to a slight degree. It is probable that the laziness and indifference sometimes observed in victims of this parasite are largely due to the great numbers of hookworms that they harbor and have harbored since they were children. The anæmic and weakened condition that a person is in all the time, if he is heavily infested, and the fact that afflicted children do not grow to maturity normally, either physically or mentally, make this indeed a serious disease, even though few if any persons die directly from its effects.

For many years, hookworms were thought to be one species of round worm belonging to the phylum, *Nemathelminthes*, but now we know that there are two species concerned, *Necator americanus* and *Ancylostoma duodenale*. These two species are so nearly alike in structure and habits that only a carefully trained person can detect the difference. Both species have two sexes showing few external differences. The worms are about three-fourths of an inch long and are a little thicker than a common pin.

These parasites attach themselves to the wall of the small intestine by means of tooth-like structures in the mouth. Not only is the intestinal lining injured by the bite but a substance is se-

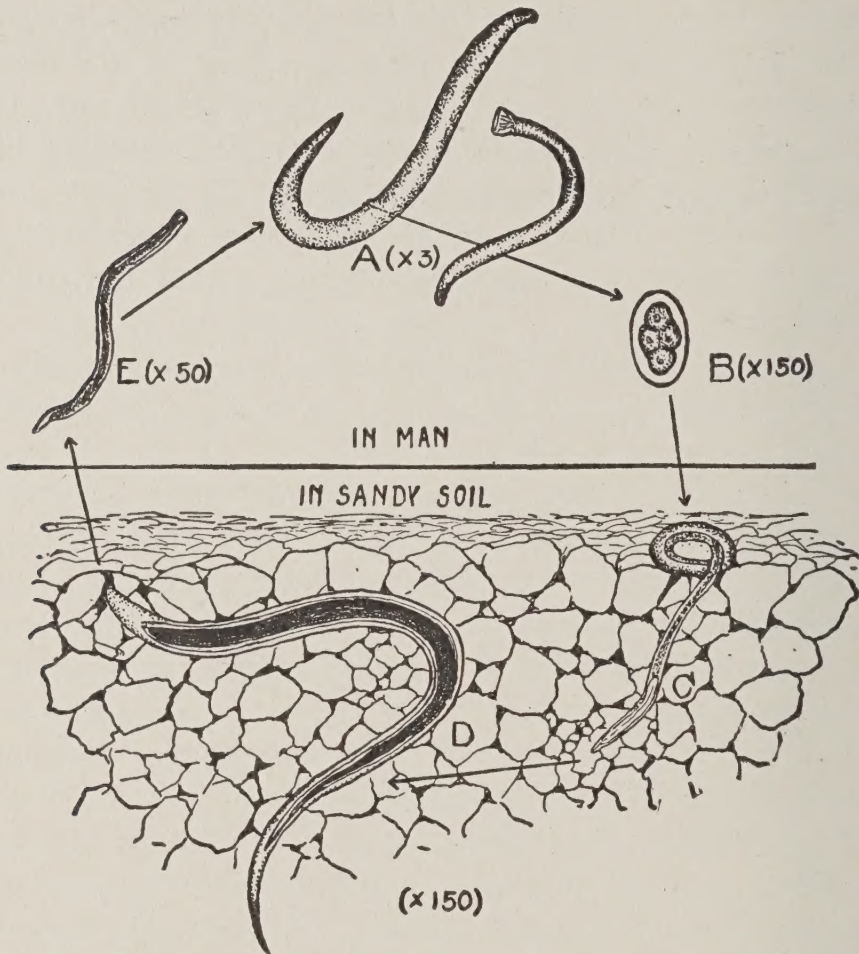


FIG. 32.—Life History of hookworm; A, adults, female and male in intestine; B, egg as passed in faeces; C, embryo hatching in ground, 24-48 hours later; D, fully developed larva, enclosed in sheath, ready to infect human being; E, larva released from sheath, migrating in body of new host. (From Smiley and Gould, from Chandler's *Animal Parasites and Human Disease*, John Wiley & Son, publishers.)

creted in the wound which keeps it from healing readily; in addition, the worms feed on human blood and produce poisonous fluids (toxins). Together these results of parasitation poison and greatly weaken the human body.

Each worm produces many nearly transparent eggs which

pass out with the fæces of the body. Before being voided, these eggs are often found in the process of development, sometimes being in the four-celled and eight-celled stages. Upon hatching, the larvæ burrow into the soil where they grow and undergo a complete moult. Upon reaching a certain stage the larvæ are ready to penetrate into the human being—usually through the feet or hands. It should be kept in mind that many adults as well as children in certain parts of the South often go barefooted, and it is well known that any child delights to get mud on and between his toes and fingers. Having gained access to the body through exposed skin, these minute larvæ make their way by means of the blood-stream to the right side of the heart, thence by the pulmonary artery to the lungs, where they burrow, eventually finding their way out through the bronchial tubes to the trachea and œsophagus. Their residence in the lungs is serious since they burrow and destroy lung tissue and introduce bacteria, often paving the way for tuberculosis and other diseases. From the œsophagus, these worms go to the stomach and thence to the small intestine where they attach themselves by teeth-like structures and begin again the life cycle. The adult stage, however, is not reached until the larva has moulted twice inside the body of man.

In cities and towns of the South where sewage is carefully disposed of, there is little chance to become afflicted with this parasite. In the country districts, it is often widespread because of the lack of sanitary outbuildings, where the human fæces can be kept from touching the soil before being treated with the right chemicals to destroy the eggs. Fortunately the prevention of this disease is comparatively simple, namely, the careful disinfection of all human fæces. The cure is likewise easy and inexpensive, but it is difficult to get some patients to take it. Thymol and oil of chenopodium are often used, but the method of treatment is undergoing change for the better year by year. If the treatment is taken in time by children, no stunting of growth physically or mentally results. Marvelous changes often ensue within a few months after the elimination of these worms from

the system. Even "lazy" and almost lifeless adults are restored to comparative vigor upon the destruction of large quantities of these hookworms in the digestive system.

Trichinella spiralis is another serious parasite of the human system, producing a disease called Trichina or Trichinosis. It also belongs to the phylum, *Nemathelminthes*. Although at one time it was quite prevalent in some parts of the world, it is not so common to-day in civilized countries, due to the fact that few people intentionally eat raw or rare pork. Occasionally an ignorant or careless individual will eat such food, thus laying himself liable to infection, since about two per cent of hogs harbor this worm. If the pork is obtained from places where strict

meat-inspection is practiced, the chance of getting trichinosis is remote, since all infected animals are discarded by government inspectors as unfit for human food.

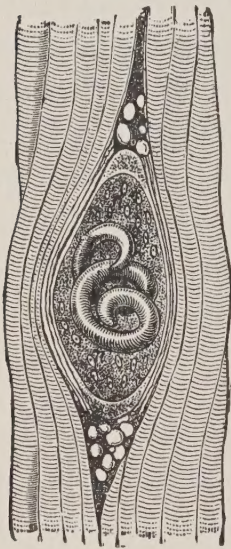


FIG. 33.—*Trichinella spiralis*, the cause of the disease trichinosis in human beings, pigs, and rats. (From Hegner, after Leuckart.)

The life history is comparatively simple. A large variety of animals, such as cats, dogs, guinea-pigs, rats, mice, and hogs, may become infected, but in this country, only the last named is of great importance in the consideration of this disease. The larvæ are encysted in meat. If raw or rare pork is eaten by man, these larvæ are freed from their cysts and lodge among the villi and folds of the mucous membrane of the small intestine. In these folds the worms come to maturity in a few days. The average length of the adult female worm is about one-sixth of an inch, of the male about half that length.

A single female will often produce as many as 1500 living young, which are usually deposited in the lymph or blood vessel of the intestine. By means of the blood stream, the larvæ are distributed all over the body, but they seem to live and encyst only in striped muscle. Here they thread themselves along be-

tween fibers and eventually coil up into loose spirals. In a short time these larvæ, increasing about ten times in size, reach a length of about one twenty-fifth of an inch. At this stage a cyst wall, somewhat lemon-shaped, begins to form and is completed in about two months. As the worms are coiled, the cysts are only about one-fiftieth of an inch or less in length. In about a half-year the cysts become very hard and calcareous in nature and usually the enclosed worm also hardens and dies after some months or years.

If the living encysted worms in the hog are eaten by man, the cyst wall is dissolved away by the juices of the stomach and intestine, and the process is repeated. Human infection probably always comes from eating uncooked pork, but the hog may get the disease from eating rats or scraps of pork. Dogs and cats may become infected in a similar way by eating infected rats, mice, and other animals.

Obviously human infection can be prevented by proper inspection, discarding infected animals, and by thoroughly cooking all pork used for food. Because many thousands of cysts may be found in a pound of flesh, it is quite impossible to operate to remove the worms. Other treatment seems to be equally futile. Because of the large number of worms that may be present in the body and because of the toxins that are consequently thrown off and absorbed by the body, the patient experiences symptoms somewhat the same as those of rheumatism and typhoid fever combined. The disease is indeed a terrible one, with the death-rate sometimes mounting to 30 per cent of the affected cases. If a person survives, the fever and pain gradually subside, leaving eventually only the numerous dead cysts in the muscle. Even these constitute a considerable handicap to the victim.

Malaria is probably the most prominent and widespread protozoan parasite that human beings now harbor. Although its complete life cycle is now known in great detail, this knowledge is less than a generation old. To be sure, several ancient peoples, particularly one group in India, surmised that mosquitoes had something to do with malaria, since they called malaria and one

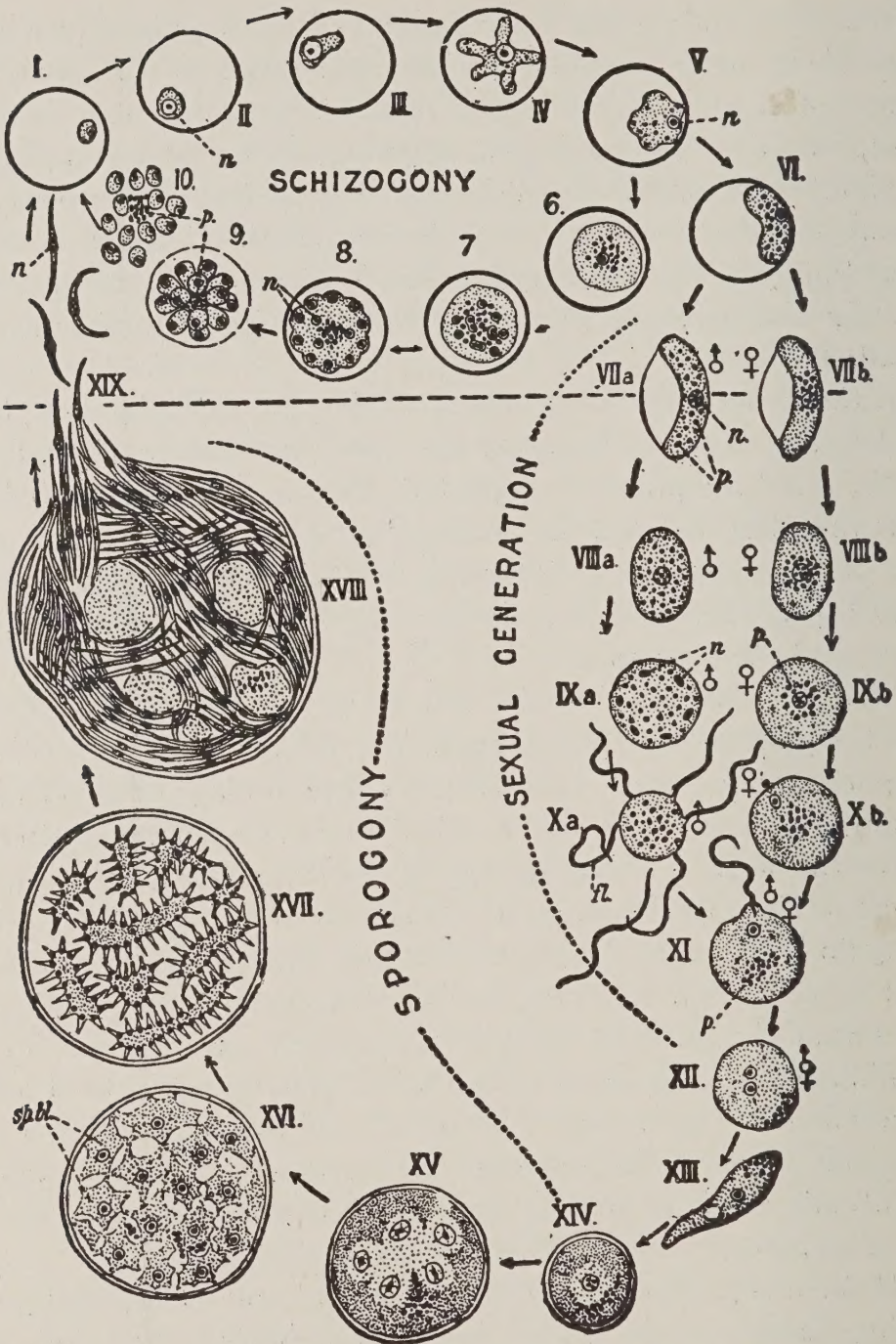


FIG. 34.—Diagram illustrating the life history of Malarial Fever parasite. The stages shown above the line of dashes are passed through in the blood of a human being; those below the line, in the body of an *Anopheles* mosquito. (From Woodruff, after Minchin.)

kind of mosquito by the same name; yet the prevailing idea was that "effluvia" arose from the swamps and caused the dreaded disease; sometimes the disease was attributed to bad night air. The period centering around the Spanish-American war and just before the beginning of the building of the Panama Canal marks the solution of the mysteries of the dreaded malarial and yellow fevers. So important was the work of the men who solved the life cycle of yellow fever and malaria, that it is said the Panama Canal could not have been dug had not this information been made available. By far the greatest contributions, however, are the annual saving of human life and the rendering of great areas available for cultivation and civilization, through the elimination of the mosquito. The draining or oiling of the swamps has eliminated malaria by destroying the breeding ground of the mosquito.

The stages in the life cycle of a typical malaria, *Plasmodium vivax*, are several. If an infected mosquito bites a human being, it introduces into the blood stream a saliva-like secretion which contains slender protozoa called *sporozoites*. These sporozoites quickly enter the red blood corpuscles which they feed on, ultimately destroying them. While feeding upon the body of the blood cell, the sporozoite changes its shape and becomes a *trophozoite*, which means a growing zoite or animal. In forty-eight hours the trophozoite has matured and broken up into about sixteen cells, each called a *merozoite*, a mere fraction of the original trophozoite. These merozoites then break out through the wall of the dead corpuscles and quickly enter other blood cells, where the same process is repeated in about forty-eight hours. In about two weeks a few hundred sporozoites infecting as many red blood cells may be increased to many millions.

At about this stage the patient has chills and fever, doubtless due to the liberation of the merozoites from the blood cells and also to the secretions and excretions of these parasites. At the end of the second week, approximately, sexual stages also begin to appear in the blood. If an uninfected mosquito now bites this patient, it gets a quantity of blood containing either

merozoites or trophozoites and sexual stages, some of which prove to be male and others female. The merozoites and tro-

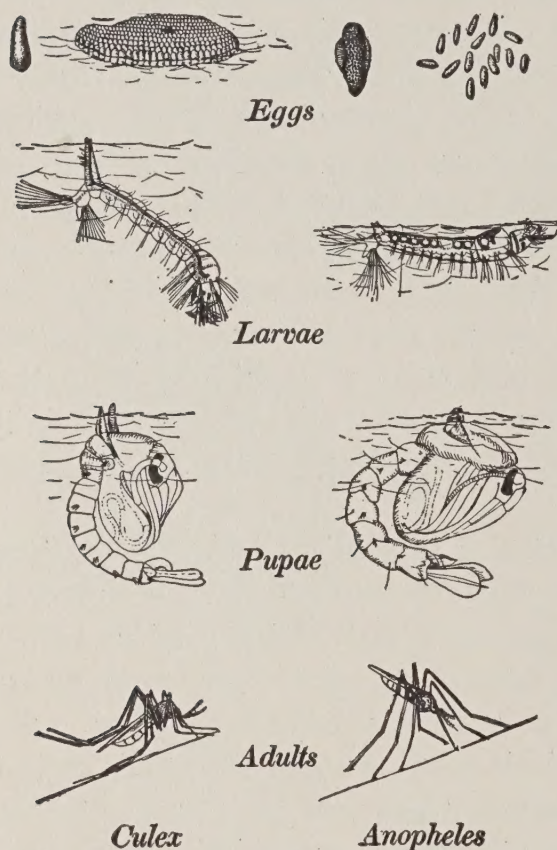


FIG. 35.—Mosquito life histories. The mosquitos of the genus *Anopheles*, which transmit malarial parasites, differ from the common *Culex* in every stage. We can readily distinguish the adults of the two genera by the fact that when at rest the *Culex* holds its body parallel to the resting surface, whereas in *Anopheles* the hind end of the body is farther from the resting surface than the head. (From Gruenberg's *Biology and Human Life*, by permission of Ginn and Company, publishers.)

phozoites are digested by the mosquito, but the sexual stages resist digestion, at least in the genus *Anopheles*. In the stomach of the mosquito the male and female stages conjugate, producing a *zygote*, which soon changes into an *ookinete* capable of boring through the stomach wall. After penetrating the muscles and other soft tissue of the mosquito, the ookinete gradually changes into a *growing cyst*. Inside the cyst hundreds of sporozoites are produced, which upon reaching maturity break out of the cyst wall that enters the blood stream, thus going to all parts of the body including the salivary glands and proboscis. In about two weeks after the first merozoites, trophozoites, and sexual stages are taken into the mosquito's stomach, the mos-

quito is able to transmit to its victim the malarial germ—the sporozoites—and thus start the vicious cycle again.

The best method of prevention is to drain the swamps where

the mosquito larvæ live, or if this is impossible to oil the swamps regularly, and after every rain if the surface film of oil has been removed. Barrels, tubs, cans, and the like should also be emptied or regularly oiled, since even small receptacles are capable of hatching and supporting large quantities of larvæ.



FIG. 36.—*Sacculina* attached to the abdomen of a crab: *ks*, the sac-like parasite giving off root-like processes that permeate the body of the host. (From Abbott, after Delage.)

No cure for the disease is known; the drug, quinine, seems to be somewhat specific. It, however, does not eradicate the germs from the system, but rather renders them inactive, thus allowing the body to recover somewhat faster than would otherwise be the case. Removal from an infested territory is also desirable in order that reinfection may not take place. Doubtless the seriousness of malaria is due in large part to the fact that a person in a malarial district becomes reinfected many times over.

The dodder plant, *Cuscuta*, is one of the most widely distributed plant parasites. It produces seed in a way similar to that of other flowering plants. These seeds germinate, under favorable conditions, developing roots and very slender vine-like stems which seize upon almost any plant that may be close by. As soon as the stem comes in contact with the plant, it sends root-like structures into the body of its host and shortly loses all connection with its own roots, depending entirely on

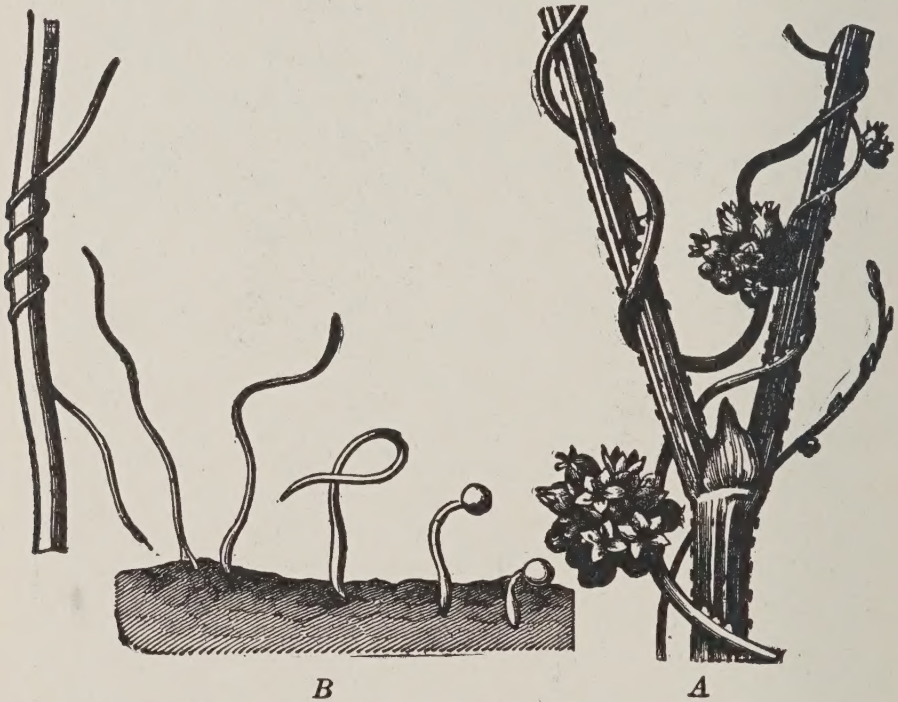


FIG. 37.—A, European dodder twining about a hop stem. All but the uppermost coils show the groups of wartlike swellings from which haustoria penetrate the host stem. Natural size. B, germination of same. The various stages are arranged in order from right to left. In the last stage the seedling has found a suitable support and has absorbed all the reserve food in the thickened lower end, which has withered and died. Magnified about two diameter. (From Abbott, after Kerner.)

the food obtained from the host. Since it gets all of its food from its host, its leaves are reduced to mere scales and are functionless. The only remaining parts are the stems, root-like structures which penetrate the host's body, and the reproductive parts. The number of seeds produced by the dodder is extremely large, which is typical of many parasitic forms.

The several bot-flies are also outstanding cases of parasitism in horses, cattle, and sheep. The horse bot-fly, *Gastrophilus equi*, fastens its eggs to the hair on the legs or shoulders of horses. The larvæ, which develop within the egg case, are licked off and swallowed, then attach themselves to the inner wall of the stomach where they grow and live until ready to pupate. When they have reached the pupa stage, they pass out of the alimentary canal and soon hatch into adult flies if the conditions are favorable. The female flies in turn after fertilization lay the eggs on the hair of the horses and thus the cycle is completed. This parasite is important since it interferes with the digestion of the horse if found in considerable numbers, and may be responsible for the extreme nervousness noticed in some horses.

The cattle tick, *Margaropus annulatus*, which causes Texas fever in cattle, is another outstanding parasite. For many years the economic loss mounted to millions of dollars annually, and even now it is a considerable sum even though the ravages have been greatly reduced through the tracing of the life cycle of the tick and through the scientific pasturing of cattle. Very briefly, the life cycle is this: After mating, the female tick sucks in an enormous amount of blood and lays a large number of eggs which are deposited ordinarily on the ground or just under the ground. In about two weeks, if the weather is favorable, the eggs hatch into "seed ticks" having only six legs. These larval "seed ticks" then crawl up on a blade of grass or something similar, waiting for the proper host to come along, to which they may attach themselves. If fortunate, they feed on the blood of the host, undergo internal changes, and then moult into an eight-legged immature nymph. The nymph also undergoes another internal reorganization, moults, and eventually becomes a mature female tick. It fills itself again with blood if it gets a chance and produces the large quantity of eggs laid by this species. These eggs in turn hatch out in a few weeks into the seed ticks, and the cycle is completed.

The ticks themselves would be merely a nuisance on cattle if it were not for a protozoan called *Piroplasma bigeminum*.

This protozoan is found in the larva, since it receives the infected blood directly by way of the egg from the infected females. This disease results in a fever which may be fatal to cattle or, at least, cause the animal not to grow or to fatten. Thus it is a parasite of a parasite that is responsible for the trouble.

The cure is in dipping the entire animal which has been found to harbor ticks. Since "seed ticks" live for only a few weeks on herbage, they will starve to death if the pasture is kept vacant for this time; then the pasture is safe for use again.

Although it is common knowledge that bacteria cause disease, perhaps they are not usually thought of as parasites. Even though microscopic in size, or even ultra-microscopic, yet they are definitely parasitic and because of their great numbers, due usually to their exceedingly rapid multiplication, many of them are serious disease producers. Ordinarily their life cycles are relatively simple, new individuals arising by simple fission from the parent individuals. Among the most common bacterial parasites of human beings are the bacterial germs of tuberculosis, pneumonia, typhoid, tetanus (lockjaw), and the many different kinds of bacteria that cause colds.

The prevention and cure of the various bacterial parasitic diseases of man are very varied, each one being in many ways different from all the others. Serums, vaccines, and injections are often resorted to in overcoming these minute organisms.

It is probably safe to say that every species of life, both plant and animal, harbors disease-producing bacteria as well as many neutral and even useful forms of bacteria. The solving of the life cycle of the disease-producing forms is the chief concern of many research workers.

In several ways the animal and plant parasites are extremely important. For our purpose they are important because they are carriers of diseases of many kinds and because they show great adaptation often expressed in terms of extreme modification or degeneration of certain parts of the body.

QUESTIONS

1. Can you imagine any reason why free-living forms would begin to lead a parasitic life?
2. Tapeworms are usually found in animals where there is a close food association. For example wolves eat rabbits. The two have in common different stages of the tapeworm's life-cycle. Can you suggest another possible tapeworm due to another close food association?
3. Show how degeneration is in one sense a high degree of specialization.
4. Why do you think that Negroes seem to be more immune to hookworm than white men?
5. Why do you think that the knowledge of the cause of malaria was delayed until nearly the year 1900 A.D.?
6. What advantages have parasites over free-living forms? What disadvantages?
7. What facts regarding parasites and their life cycles give us a better understanding of the laws of health?
8. Which of these facts, if any, could be profitably taught in the elementary school? In the junior high school? In the senior high school?
9. Can you make a child parasitic in his habits by helping him too much?
10. What happens to a child when he is helped too much by the teacher? When helped too little?
11. Is it possible to lose mental traits in much the same way as physical traits are sometimes said to be lost, through lack of use? If so, give examples.

CHAPTER XV

THE PALEONTOLOGICAL RECORD

The real ancient history of important types and species of plant and animal life—Man's beginning and duration on the earth—Why some species are found in almost all strata of the earth's crust—Why man's fossil remains are found only in the upper strata—Child traits older than adult traits.

Without a general knowledge of the important facts and principles concerning the earth's geologic history and the animals and plants that have inhabited it from its beginning, one cannot possibly have an adequate conception of present living things. It is particularly true that little genuine understanding concerning man and his offspring, the child, can be had unless one knows something of the paleontological record of living forms.

The sciences of paleontology and geology, like most other branches of knowledge, may be said to have had their origin with the Greeks before the Christian era, but little was done in these fields until approximately one hundred and fifty years ago. Indeed, most of our accurate information has been collected during the past one hundred years, and by far the greater part of this within the past half-century. The rate of increase in the acquisition of paleontological information seems to be accelerating year by year.

For years three important questions have been asked more and more frequently: (1) How old is the earth? (2) How long has life been on the earth? (3) When did man first come into existence? Each of these questions is important, and satisfactory answers will greatly help in solving many problems.

It is impossible here to describe how scientists have reached their conclusions regarding the age of the earth. Suffice it to say that the best and most exact information from many sources has been brought to bear on this problem. The astronomer has

his method of determining the approximate age of this planet, as have also the physicist, the chemist, the paleontologist, and the geologist. Perhaps the geologist makes the greatest contribution, since an hypothesis concerning the age of the various strata of the earth has been requisite to the study of the various phases of geology.

If we compare the figures given by the astronomer with those of the physicist, the chemist, the paleontologist, and the geologist, we are struck with the great variation in the answers. Even scientists in the same field differ widely among themselves, so that no exact number of years can be put down as the age of the earth. There seems to be, however, quite general agreement on two points: first, that the earth is not less than four hundred million years old; and second, that the more recent and the more careful the investigation, the further back is the probable age pushed. Many prominent scientists say that the earth is at least five hundred million years old. The written history of mankind covers scarcely ten thousand years, which is less than one four-hundredth of one per cent of the minimum estimate of the earth's age. Stated in another way, written history corresponds to but two seconds of the age of the earth if the latter be reckoned as twenty-four hours.

The answers to the second and third questions are somewhat easier to give and are more nearly accurate. No scientist qualified in his own field to answer these questions, puts the beginning of life at much less than one hundred million years ago and the beginning of the human species at less than a half million years ago. It is true that many qualified persons place man's beginning at more than five hundred thousand years ago; but the majority of scientists still feel that the evidence is not sufficient as yet to extend this period further back.

One who wishes to be intelligent on the subject of paleontology must necessarily learn a few scientific names. Although the number of names will be kept at the minimum, the list may still seem long. It is impossible to discuss the scientific phenomena of any science accurately without using scientific terms.

Paleontologists quite generally agree that the life of the earth can be divided into six great divisions, called *ages* or *eras*. Beginning with the oldest they are: *Archeozoic*, *Proterozoic*, *Paleozoic*, *Mesozoic*, *Cenozoic*, and *Psychozoic*. *Archeozoic* means “very ancient age,” often called *the lifeless age*, since no direct evidence of fossil life has been found in it. However, there are many paleontologists who believe that the large amount of graphite found in strata of this age is an indication of life. Such persons hold that graphite is a highly metamorphosed product, really fossil coal. The iron ore found here is also thought by some to be the result, at least in part, of the action of primitive plants and animals. The *Proterozoic* means the “age of one-celled plants and animals” largely. The *Paleozoic* means the age of “ancient life,” and at one time it was thought to be the most ancient age, hence the great similarity in name to that of the *Archeozoic*. The *Mesozoic* means “the middle or mediæval age,” given when there were only three well-defined ages—*Paleozoic*, *Mesozoic*, and *Cenozoic*. The *Cenozoic* means the “recent age,” although there has since been added the *Psychozoic*, which is now universally agreed upon as the “most recent age,” dating back to about five hundred thousand years ago.

GEOLOGIC CHRONOLOGY

ERAS	PERIODS ¹	CHARACTERISTICS
Psychozoic (Age of man.)	<i>Recent</i> : First scientific knowledge.—Rise of civilization.—About 20,000 years ago.	Dominated by mind.
	<i>Pleistocene</i> : First true man.—Dawn of reason, art, and industry.—About 500,000 years ago.	Dominated by primitive man.
Cenozoic (Age of mammals and flowering plants.)	<i>Pliocene</i> : First man-like animal.	Dominated by mammals and flowering plants.
	<i>Miocene</i> : Culmination of mammals.	
	<i>Oligocene</i> : First higher mammals.—First modern birds.	
	<i>Eocene</i> : Great divergence and evolution of primitive mammals.—About 20,000,000 years ago.	

¹ Age estimates according to Dr. Charles Schuchert (Yale). Concurred in by Dr. J. J. Galloway (Columbia).

GEOLOGIC CHRONOLOGY—*Continued*

ERAS	PERIODS	CHARACTERISTICS
Mesozoic (Age of reptiles and medieval floras.)	<i>Cretaceous</i> : First placental mammals.— First flowering plants. <i>Jurassic</i> : First birds. <i>Triassic</i> : First non-placental mammals, Marsupials.—About 75,000,000 years ago.	Dominated by reptiles: Dominated by reptiles and medie- val floras.
Paleozoic (Age of invertebrates, fish, amphibians, and ancient floras.)	<i>Permian</i> : First land vertebrates. <i>Carboniferous</i> : First reptiles.—First true insects. <i>Devonian</i> : First amphibians.—First forests. <i>Silurian</i> : First lungfishes.—First air- breathing animals. <i>Ordovician</i> : First vertebrate fish.—First land plants. <i>Cambrian</i> : All invertebrate phyla present, all marine.—About 225,000,- 000 years ago.	Dominated by amphib- ians and coal-forming ancient flo- ras. Dominated by fish and ancient floras. Dominated by inverte- brates.
Proterozoic (Age of primitive plants and animals.)	<i>Killarney</i> : No stratified rock found and consequently no fossil remains. <i>Keweenawan</i> : First known animals, pro- tozoa, sponges, euripterids. <i>Animikian</i> : Primitive plants quite abun- dant. <i>Huronian</i> : First known plants, bacteria, and algæ. <i>Algoman</i> : No fossils found. <i>Sudburian</i> : No fossils found.—About 350,000,000 years ago.	
Archeozoic (Ancient life. No fossils found. Indications of life only.)	<i>Laurentian</i> : No fossils found. <i>Keewatin</i> : No fossils found. <i>Grenville</i> : Oldest rocks, limestone forma- tion.—About 500,000,000 years ago.	

From the outline of geologic chronology found on pages 166-167 it can readily be seen that in a very remote era, the *Proterozoic* age, there were mostly the very simple forms of life. In the *Paleozoic* age life became more complex; in the *Cambrian*, only invertebrates were found; but in the following period, the *Ordovician*, fish scales have been found which represent the lowest form of vertebrate life. The next highest class of vertebrate life, the *Amphibian*, is found in the *Devonian*, and the third highest class of vertebrates, the *Reptile*, is first found in the *Carboniferous*. The two highest forms of vertebrate life, the birds and the mammals (Marsupials) are found in the *Jurassic* and *Triassic* respectively, although the placental mammals are not to be found until the *Cretaceous*. Finally man, the highest of mammals, comes into existence at the very top of the *Pliocene* period or at the very bottom of the *Pleistocene*.

If one studies the sequence of the appearance of life carefully, one is struck by the fact that the complexity of structure increases the nearer the *Psychozoic* age is approached. The evidence of the succession of life found in the rocks cannot possibly be doubted by those with minds open to accept the truth wherever found. This evidence agrees completely with what zoölogists have held for some time—that higher forms must have been preceded by the lower and simpler forms, since the former were ancestral to the latter. The *Psychozoic* age, the age of intellect, was possible, according to the zoölogists, only after the lower mammals came into existence, and this idea is clearly confirmed by the paleontologists, who do not find the remains of human beings until the *Pleistocene* strata have been reached.

The *Psychozoic* age is dominated by man, not because he is the most abundant, the largest, the strongest, or the fleetest, but because through the power of intelligence he is able to control most of the other species of the earth most of the time.

The reader should study carefully and may well memorize the geological ages and the periods within each age. Only the briefest outline and the fewest possible subdivisions are given. The *Jurassic* alone has one hundred and forty-one well-established

divisions, and others have nearly as many. All of the periods have at least several subdivisions.

The reader will notice that in the periods preceding the *Huronian* no form of life is definitely known to have existed, since there are no fossil specimens, although there are several indirect indications of life, such as graphite and certain kinds of iron. As stated above, the former is thought by many geologists to be a form of fossil coal and the latter may be due to algæ and iron-precipitating bacteria. The beginning of the Huronian is now thought to indicate the era of the first fossil life, and this was about three hundred million years ago.

In the limited space of one chapter, it is obvious that only a few of the most outstanding facts of paleontology can be listed (see the Bibliography):

1. The lowest strata of rocks in a column are the oldest and the upper strata the youngest.
2. More species of animal and plant life have lived, failed, and have gone out of existence than there are species now living.
3. Only the lowest forms of plant and animal life are found in the lower strata.
4. As the *Psychozoic* age is neared, life becomes more and more highly specialized and complex.
5. *Homo sapiens* is found only after all the other important types of animal life had come into existence.
6. Water plants were in existence before land plants.
7. Water animals were in existence before land animals.
8. Non-flowering plants were in existence before flowering plants.
9. The first air-breathing animals appeared in the *Silurian*.
10. The giant reptiles first appeared in the *Triassic*.
11. The toothed birds first appeared in the *Jurassic*.
12. The grasses appeared in the *Eocene*.
13. At the end of the *Permian* period there was the greatest extinction of life. Large groups were blotted out.
14. Coal was produced in greatest abundance in the *Carboniferous*, *Cretaceous*, and *Miocene*. Coal is almost entirely a product of plant life.
15. Oil is found in greatest abundance in the *Carboniferous*, *Creta-*

ceous, and *Miocene* rocks. Oil is the accumulated residue of plant and animal life.

16. The continent of North America has remained relatively in the same position throughout all ages, but most parts have been under the ocean several times.
17. In the *Ordovician* period more land of North America was under the ocean than at any other time.
18. In the *Permian* period more land of North America was above the ocean than at any other time, except possibly the present.
19. The present Appalachian Mountains were formed in the *Permian*.
20. The present Rocky Mountains were first folded in the *Cretaceous* and pushed up to their present height in the *Pliocene*.
21. The Sierra Nevada Mountains were folded in the *Jurassic* and pushed up to their present height in the *Pliocene*.
22. The Coast range of mountains along the Pacific was formed in the *Pleistocene* and the *Recent* periods. In some places to-day these mountains are rising several feet a year.
23. Man is the most widely distributed of living and fossil species.

Very often the questions are asked: "What do fossils look like, and where does one find them?" Fossils may be classified in various ways; perhaps the simplest classification is somewhat as follows:

FOSSILS OF ALL TYPES AND KINDS

I. Actual Remains

Unaltered

1. Soft parts—mummies, in amber, in ice.
2. Hard parts—bones, teeth, claws, scales.

Altered (petrified)

1. Silicified.
2. Calcified.
3. Pyritized.
4. Carbonized.

II. Indications of Life

1. External molds.
2. Internal molds.
3. Casts (Pseudomorphs).

4. Imprints—only one side, otherwise like molds.
5. Tracts, trails, burrows.
6. Copraliths (fossil fæces).
7. Artifacts (something made by man, as pottery, arrowheads, etc.).

In the usual parlance, fossils are either petrified remains of life or molds of some form of life. Actually a fossil may be any of the above, and in this discussion we shall include all types.

A common question is, "How old must a specimen be before it is called a fossil?" Ordinarily we think of a fossil as something that has been dead a long time or as something that has become petrified. Actually anything that is dead, even if only for a day, is a fossil. We have many fossil remains of species still in existence; so the length of time life has been extinct is not a factor in the terminology.

Another question is, "Where are fossils found?" The answer is difficult to give except in a general way. Sometimes the remains of life are found in caves, in asphalt pits, in amber, in ice, but typically, fossils are found in stratified rock. These strata may subsequently be folded or in some cases turned on edge, but usually they remain somewhat horizontal. So far as we know, strata are deposited only by the action of water and wind in low places such as valleys, lakes, deltas of rivers, or the ocean. Often these strata may be found far higher than the surrounding territory, even occupying the top of a high mountain, but in such cases the present elevation has been accomplished by an upheaval subsequent to the deposition of the strata.

It is easy to understand why only stratified rocks contain fossils if one understands their origin and compares them with the igneous rocks. The latter when found near or at the surface are there because they have been pushed up either by internal action or by the overflow from volcanoes. In either case it would

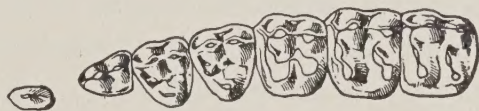


FIG. 38.—Upper teeth of *Eohippus*, the four-toed horse. Short-crowned, no cement, premolars simpler and smaller than molars. Natural size. (From Lull, after Matthew.)

be impossible for them to contain fossil life, unless by chance later fossils might fall into the cracks and crevices of these rocks. On the contrary stratified rock could easily contain fossil life since the fossils would be deposited in the strata along with and at the same time as other material such as gravel, pebbles, sand, and the like. If a natural cement be added, together with pressure, we should have solid rock composed of a variety of substances, enclosing whatever hard substance of animal or plant life might chance to have become embedded.

Ordinarily only hard parts of animals, such as bones, teeth, nails, claws, shells, are preserved and petrified; the soft parts tend to decay before they can be preserved. It seems that nearly all fossilization takes place under water. Decay is usually much slower here, especially if the water is moving; consequently, the mineral in the water almost immediately begins to replace the

soft parts. About the only alternative is for the soft parts, such as flesh and internal organs, to dry up and later to be replaced molecule for molecule by mineral in solution in the water.

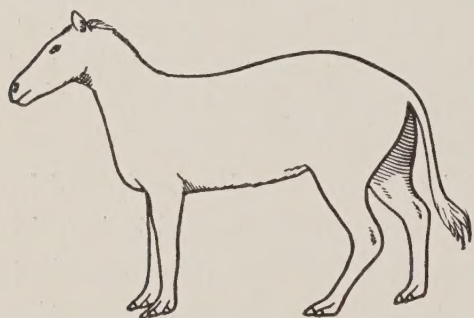


FIG. 39.—Restoration of four-toed horse, *Orohippus*, middle Eocene, Wyoming. (After Lull.)

There are very few cases of true fossilization of flesh, other than by mummification. Nearly all “petrified men,” “petrified giants,” or “petrified animals” are proved to be spurious when

once a scientist is allowed to investigate. There are in America, however, at least two cases of genuine fossilization of flesh—one that of a reptile of the Mesozoic and the other that of a human being caught in a copper mine by the falling in of the roof. Both of these specimens are in the American Museum of Natural History in New York City.

Perhaps the strangest method of fossilization, using the word in the broadest sense, is that by which specimens of some by-

gone ages, now extinct, are enclosed in ice in almost perfect condition. Even some of the undigested plants in the stomach could be named, in the case of some of the mastodons and mammoths so fossilized. The writer was told by prominent members of the Carnegie Institute of Pittsburgh that they had either tasted soup or had eaten meat of these mammoths. The writer's own grandfather in northern Sweden had a "beef steak" carved from one of these mammoths,¹ which was sold from a butcher shop in the city of Ostersund as fresh meat. This particular mammoth was discovered by dogs during the winter season. Since the dogs seemed to be fatter that winter than ever before, with no apparent increase in food supply, they were traced to a near-by ice drift or glacier and there was found part of the body of the mastodon exposed.

In order to grasp the real significance of the difficulty in maintaining life, over long periods of time, emphasis should again be placed upon the fact that a greater number of different species of life have come into existence and have perished because of the lack of ability to adapt themselves than there

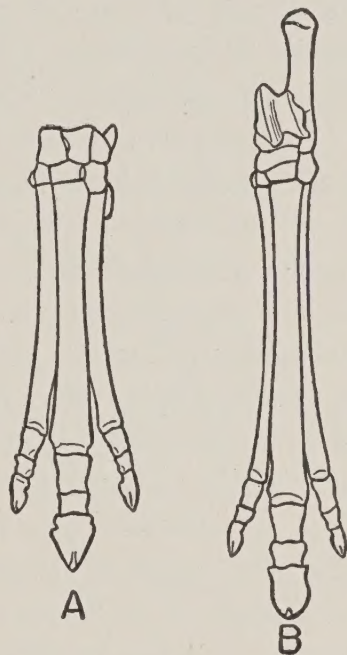


FIG. 40.—Three-toed horse, front and back. (From Lull, after Marsh.)

are now species living. Many paleontologists hold that less than one-fifth as many species are now living as have lived during the many periods of the earth's history. This is probably due to the fact that the earth's surface has changed often and that all forms of life have had to adjust themselves to the ever-changing environment or perish. Some have been able to do this and consequently have survived, while the majority have not been able to change rapidly enough and therefore are known only as fossils, if they are known at all. In some cases, of course, animals

¹ Probably *Elephas primigenius*.

may have migrated to more favorable regions, which of course is one means of "adjustment."

In certain geological periods it has been more difficult for life to survive than in others, because of the great upheavals of mountains, the lowering of large areas forming marine or inland seas, the drying up of large regions, and the cooling off of vast areas due to enormous ice caps. Perhaps the most difficult of all times was the close of the Permian. Some paleontologists think it surprising that any life survived at all, so radical were the changes at that time.

Perhaps the reader has said to himself many times, "How does one determine that this stratum is older than that one, and that this form of life did not come into existence until after that one?" Although there are certain areas even yet where the period represented is not yet determined definitely by geologists and paleontologists, yet in the great majority of cases one simple rule will apply. If one studies the formation of the delta of a river or the natural filling in of a lake, one finds that there are differently colored layers of soil. Now it is perfectly obvious that the lower layer was deposited first and the upper layer last. In precisely the same way, only over enormous areas, thousands of geologists have studied the exposed strata of the earth's surface in cañons and valleys, on hills and mountain sides, and occasionally in mines and holes drilled in the earth's crust. They have found that a certain layer or stratum in one area can often be traced accurately to a remote area and that the same materials will be found embedded in both places. After much checking and testing, paleontologists are now able to tell the age of a stratum by the fossils embedded in it, by the absence of certain fossils, by the complete absence of fossil life, or by the rock itself. Anyone who will take time to study carefully the methods used by paleontologists and geologists to determine the age of rocks and fossils is certain to be convinced of the soundness of their procedure. For detailed information the student is referred to the bibliography which lists authoritative texts in geology and paleontology.

It is easy to understand why the higher forms of animal and plant life are found only in the upper strata, but it may be more difficult to understand why some species have persisted with little modification since very early periods. This is particularly true of some of the protozoa, molluscs, and brachiopods. It seems very probable that these species live in an environment that has changed but little. These animals are almost invariably

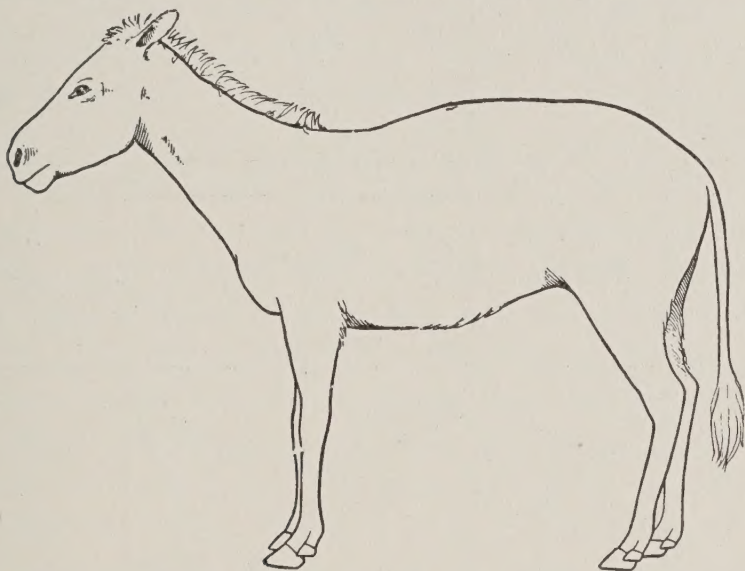


FIG. 41.—Restoration of the Miocene prairie horse, *Merychippus*.
(After Lull.)

found in the ocean. If they had long ago successfully adapted themselves in a high degree to certain parts of the ocean and if these certain parts of the ocean had changed but little during all these periods, as is believed to be the case, then it would seem only probable that these species would have changed but little, and that they would have persisted.

Perhaps the species showing the most interesting adaptations throughout long periods of time is the horse; and in no other species have we found a more complete series of the several stages of development. The chart on page 180 illustrates in detail the development of the skull, the feet, and the teeth of the horse.

The first trace we have of the horse is in the *Eocene*, when he

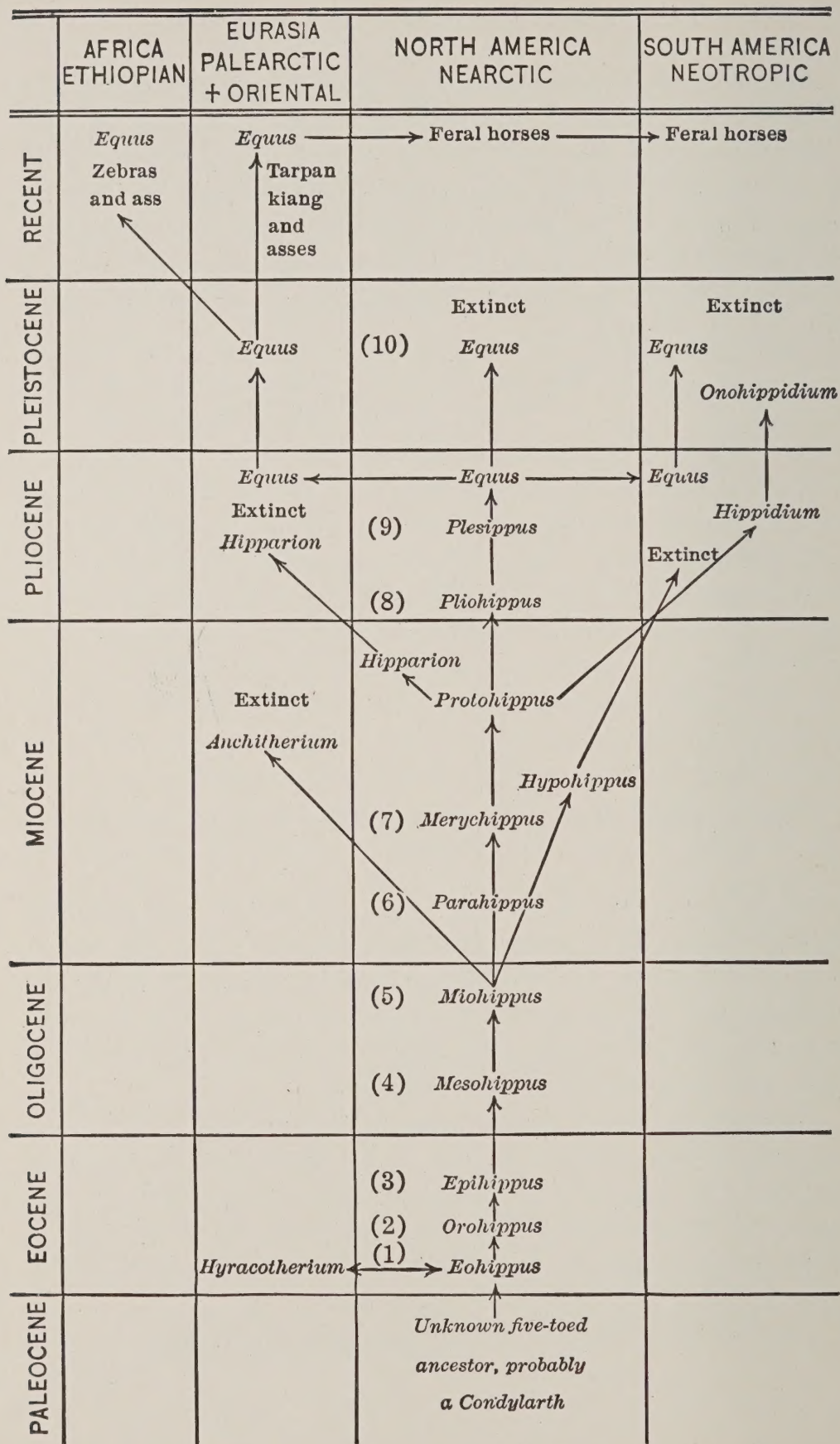


FIG. 42.—Phylogeny of the horses. (After Lull.)

was about fourteen inches tall, and looked much like a carnivorous animal. Indeed it is thought by many that the *Carnivora* are ancestral to the horse family, *Equidæ*. In America, in the Great Plains region, where the primitive horse was most abundant, the front feet had four toes each with a remnant of the fifth, and the hind feet three toes each, with a remnant of the fourth. These feet were similar to those of the dog, adapted more to a marshy region than to the dry plains where the horse now seems to fare the best. It is well known that at the time the four-toed horse was abundant the Great Plains area had only recently been under the sea, and doubtless many marshy places still remained. As the plains dried up, the horse had to depend more upon speed than upon dodging its enemies in the swamps and consequently had to take to its toes. Now it is well known that all animals get up on their toes if they wish to attain great speed, and the horse was no exception. Even man does not touch his heel to the ground when running rapidly. In attaining speed, horses with the largest middle toes had a decided advantage; hence selection worked to increase the size of the middle toe while the rest of the toes were much reduced. Finally the one-toed and one-hoofed stage was reached. The hoof of the horse is only the middle toe-nail greatly enlarged and turned under. (See Chapter V.)

At the same time that the feet were undergoing change, the horse's head was enlarging, and the teeth were changing from a short primitive type with little enamel to a complex long type with much enamel and highly adapted to the eating of grass. There are those who say that the horse's teeth are the best and most perfectly adapted teeth in existence.

Those who would see the evolution of the horse from the time that it was no larger than a fox with four toes on each front foot and a remnant of a fifth, to the specimen of to-day, need only visit the Peabody Museum of Yale University, the American Museum of Natural History in New York City, or almost any other large museum. At both places representatives of the several stages of development can be found.

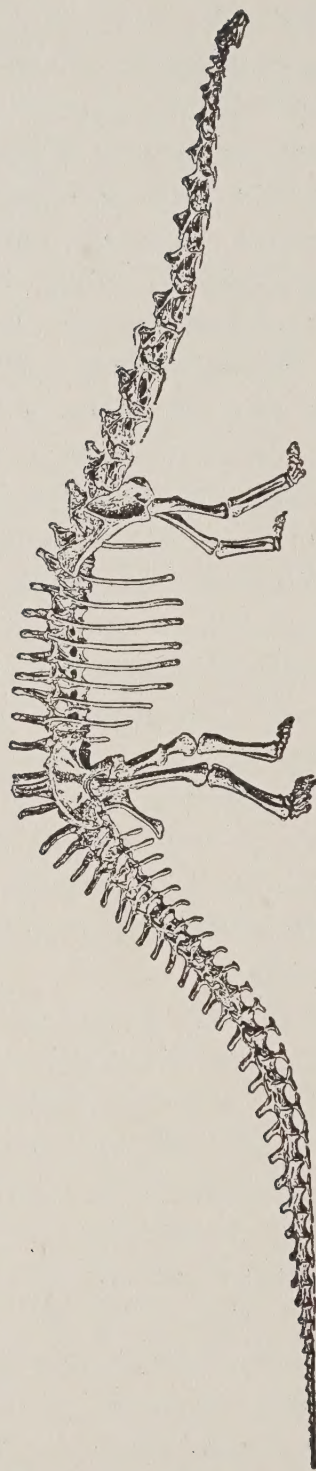


FIG. 43.—Skeleton of the sauropod dinosaur, *Diplodocus carnegiei*, Morrison (Comanchian), Wyoming. From the skeleton mounted in the Carnegie Museum at Pittsburgh. (From Lull after Hatcher.)

Almost as conclusive evidence of the loss of toes by the modern horse can be had if the leg bones are examined. On each of the lower leg bones of the horse, really the carpals and the tarsals, can be seen two splint bones, the vestigial remains of the second and fourth toes.

If there were sufficient time, a similar story could be told of the development of the camel and the elephant in North America. It is only comparatively recently that these types have vanished from the western hemisphere.

In an attempt to summarize, at least three points stand out in bold relief: first, life has been on the earth for many millions of years; second, the higher forms of life could not possibly have come into existence before the lower forms, because the latter are ancestral to the former; and third, the lower strata of rock were necessarily deposited before the upper strata. Upon these three fundamentals is built most of the science of paleontology. When one understands these facts thoroughly, one can understand why it is useless to look for human fossils in the lower strata.

If it were necessary to produce other data to uphold the findings and interpretations of paleontologists, such evidence could easily be found. It will be shown in Chapter XVIII that the embryonic and post-embryonic development of most of the higher forms of life, such as birds and mammals, parallels to a great degree their paleontological history—that is, the embryonic and post-embryonic development of such prominent structures as teeth, feet, skull, etc., are in sequence very much like that found in the rocks, beginning with the lower strata and working upward. The paleontological record corresponds with the embryological record to an astounding degree. One might go so far as to say they never disagree as to the sequence in the development of a part of an organism.

Paleontology and embryology may well be said to give us the real ancestral or ancient history of the development of animal and plant life and therefore have much of value to the student, particularly the prospective teacher who should have the historical perspective whenever possible.

THE EVOLUTION OF THE HORSE.

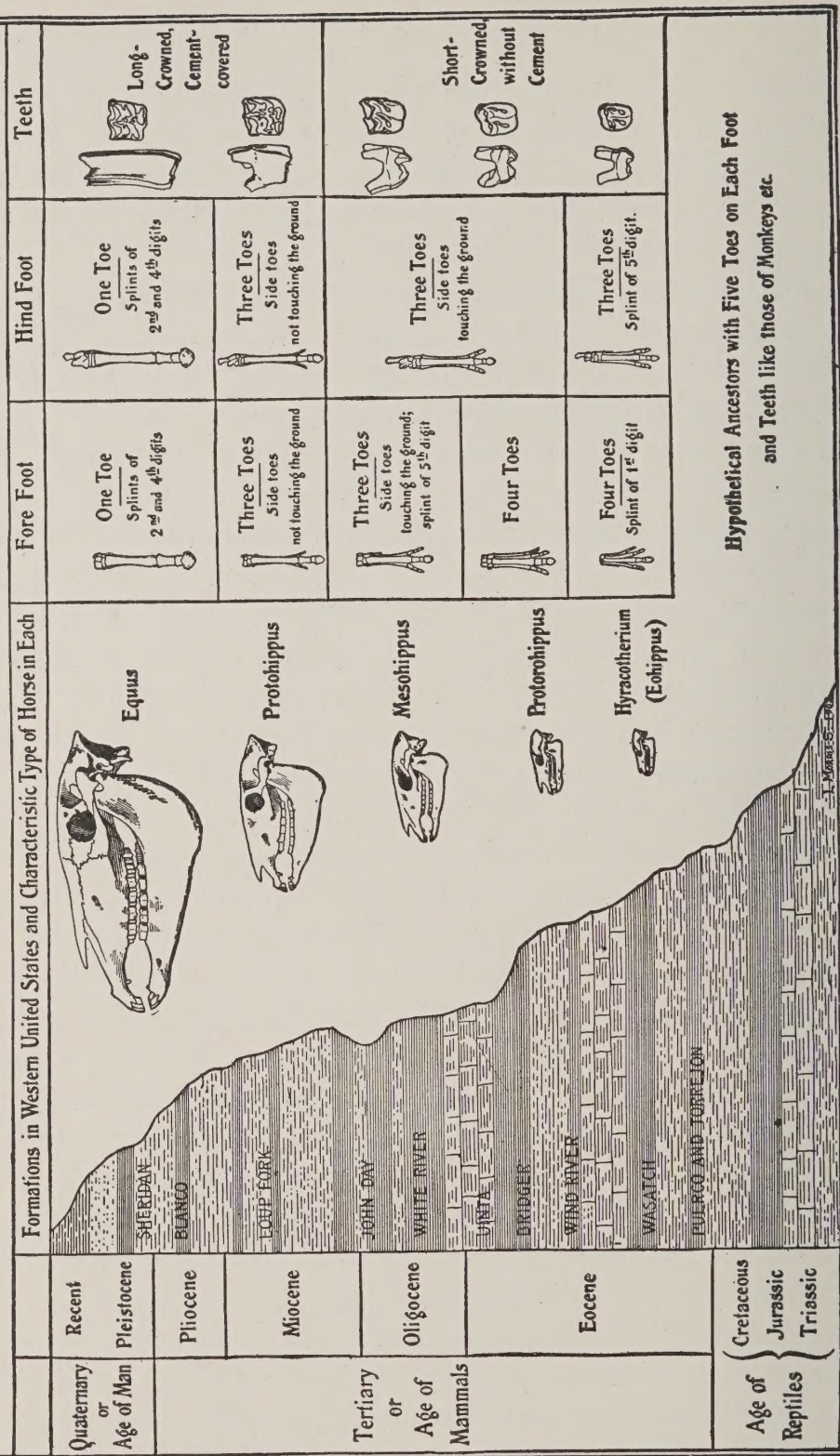


FIG. 44.—Illustrates the evolution of the horse's head, fore foot, hind foot, and teeth. (From Abbott, after Matthew.)

FIG 45.
 -Restoration of the
 American
 Mastodon
 (*Mastodon
 Americanus*). (From
 Scott, restored
 from a skeleton
 in the Museum of
 Princeton University.)



QUESTIONS

1. Distinguish between the sciences of geology and paleontology. Why do you think that these sciences have only recently been developed?
2. What reasons can you advance for the several ice ages that appeared in North America? Do you think there will ever be another ice age?
3. Can you suggest reasons why life probably appeared first in the water?
4. Why do you think that large body size seemed to be the early trend of evolution, as exemplified by the giant dinosaurs in the Triassic and Jurassic, while now the trend seems to be toward a larger or better brain and a smaller body size?
5. Why should the paleontological record of man and the embryological record support each other in the better understanding of mankind, particularly of the child?
6. How has your study of paleontology or geology influenced or changed your conception of man and his offspring the child?
7. Explain how it is possible, biologically, to say that the child is older than the parents.
8. What lessons taught in geography classes would be illuminated by knowledge concerning fossil life?
9. What facts set forth in this chapter could be understood by fifth-grade children? By ninth-grade children? Would it be advisable to teach such facts in the grades mentioned?

CHAPTER XVI

THE CELL: THE UNIT OF LIFE

The one thing common to all plants, all animals, and human beings—Its structure and functions—Cell division—How growth takes place in young plants, in young animals, and in children.

To have an adequate conception of life, particularly of the higher forms and more especially of that most complex vertebrate of all, the child, it is necessary to know about the cell—the unit of life out of which every living thing is made.

Apparently the only structural character that is common to all life, both plant and animal, is this unit, which for nearly a century has been called the cell. To be sure, the term “cell” is generally recognized to be a poor name, but the word is evidently too well fixed in the English language to be dropped now. As early as 1665, at about the time when the compound microscope was first used, Robert Hooke of England observed in cork “little boxes or cells distinguished from one another.” It was not until 1838, however, that the cell theory, as we now know it, had its beginning. Two men working independently, Matthias Jacob Schleiden (a botanist) and Theodor Schwann (a zoölogist) observed that all the forms of life that they examined were made up of separate units. Many other workers in biology confirmed the findings of these two men, with the result that the cell theory was developed. The discovery that all life is built on a similar plan, that is, out of similar units, was epoch-making in that it changed radically many of our conceptions regarding plant and animal life.

The simplest forms of plant life, such as bacteria and yeasts, have but one cell, and are called *Protophyta*; whereas the higher forms of plant life—such as columbines, sunflowers, and dande-

lions—have many cells and are called *Metaphyta*. The former group includes one-celled plants and the latter group, many-celled plants.

The simplest forms of animal life, such as the amœba and paramecium, likewise have but one cell and are called *Protozoa*;

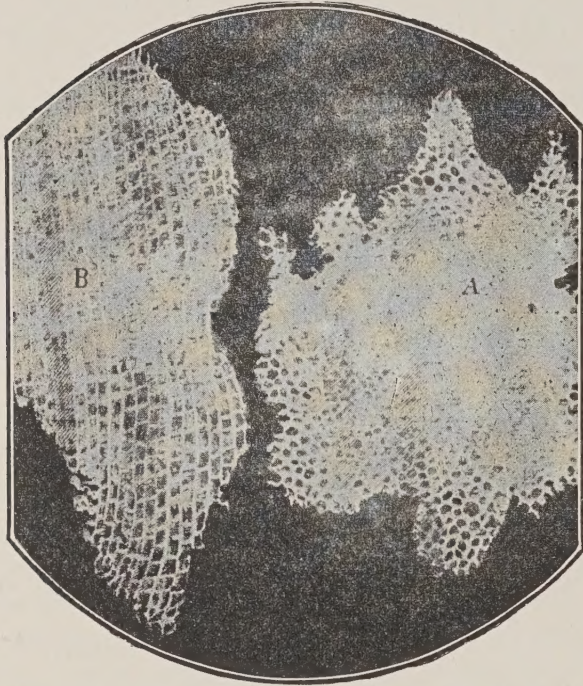


FIG. 46.—The earliest known picture of cells, from Hooke's *Micrographia*, 1665. From the edition of 1780. (From Loey, *Biology and Its Makers*, by permission of the publishers, Henry Holt and Company.)

whereas all the higher forms of animal life, including the human being, have many cells and are called *Metazoa*. The former group includes one-celled animals, and the latter group, many-celled animals.

Although nearly all of the protophyta and protozoa are visible only under the microscope, the structural differences are even greater than such a statement might indicate. The germs of influenza are among the smallest known cells visible under the highest power of the best microscope; the typical cell is

about $\frac{1}{50,000}$ of an inch in length. The tubercular bacillus, a typical germ, is about $\frac{1}{5000}$ of an inch in length. The common protozoan, *Paramecium caudatum*, is relatively very large, about one twenty-fifth of an inch in length, and can be seen, under optimal conditions, with the unaided eye.

Many bacteriologists and protozoölogists are sure that there are forms of life not visible under the highest power of the best microscope, so small that they will pass through the finest filters. Evidence to the effect that there are ultramicroscopic forms of

life is accumulating year by year from different sources. In no other way, it seems, can the spread of certain diseases, such as rabies and smallpox, be explained; and it certainly is not in-

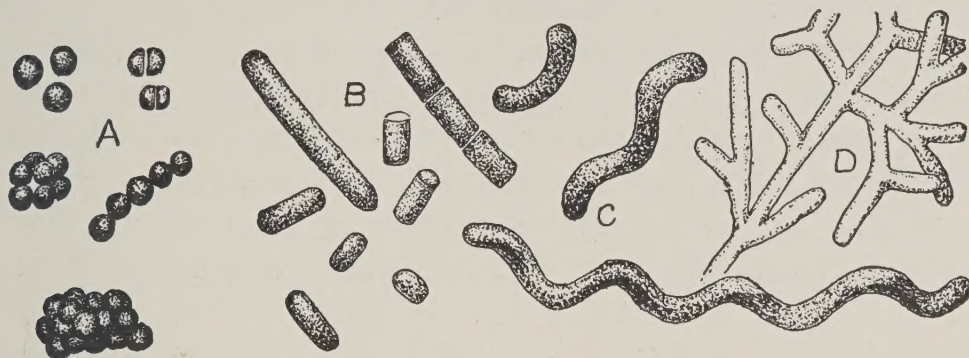


FIG. 47.—The four types of bacterial cells, some of them showing asexual reproduction. A, cocci; B, bacilli; C, spirilla; D, branched filamentous organism. (From Buchanan.)

dicative of the scientific mind to assume that, because we cannot now see an organism, it does not exist. Before the invention of the compound microscope in the seventeenth century, scientists assumed that there was no life smaller than that which the un-

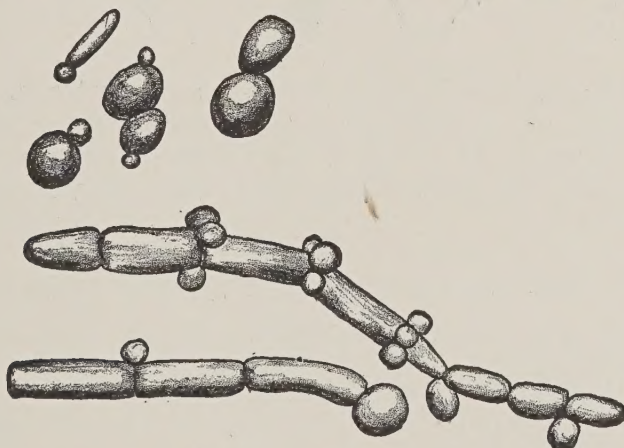


FIG. 48.—One type of asexual reproduction. Various types of budding yeast cells. (From Buchanan, after adaptation from Hansen.)

aided eye could see. We now know how erroneous this assumption was. It would probably be equally erroneous to assume that everything that will ever be seen can now be seen with our best microscopes.

The largest species of plant life ever known to have existed is the giant redwood of California. In one tree of this species, measuring over thirty feet in diameter and nearly three hundred feet in height, there are billions of cells. In the sulphur-bottom whale, which is the largest known species of animal life, whether living or fossil, there are also billions of cells. However, the size of an animal or plant is not determined entirely by the number of cells that it contains, since the size of the various kinds of cells is also an important factor. Two species of equal size do not necessarily have the same number of cells; they may differ as

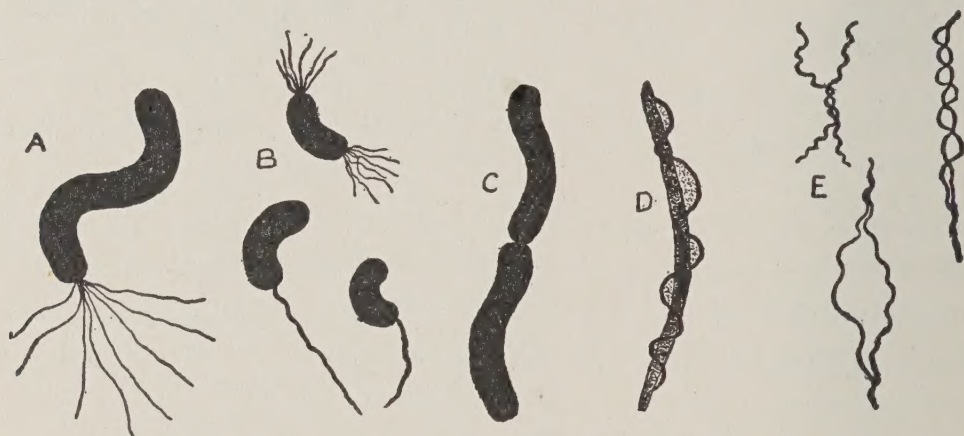


FIG. 49.—Integrations between bacteria and protozoa. A, *Spirillum*; B, *Microspira*; C, *Spirosoma*; D, *Spirochaete*; E, *Treponema*. A, B, and C are bacteria; D and E are usually called protozoa, although considered bacteria by others. (After Buchanan, except D, adapted from Gonder.)

much as fifty per cent or more, in the number of cells in their bodies. However, similar cells in the same species, such as muscle cells, are very nearly the same in size.

Some of the largest cells known are to be found in citrus fruits and in birds' eggs. In a slightly dried orange one can quite readily see cells that are about one half an inch in length and about one tenth of an inch in diameter. The yolk of an ostrich egg, just before fertilization, is probably the largest living animal cell known. However, as stated before, nearly all cells are visible only under the microscope and almost nothing of importance about the cell can be ascertained without this instrument.

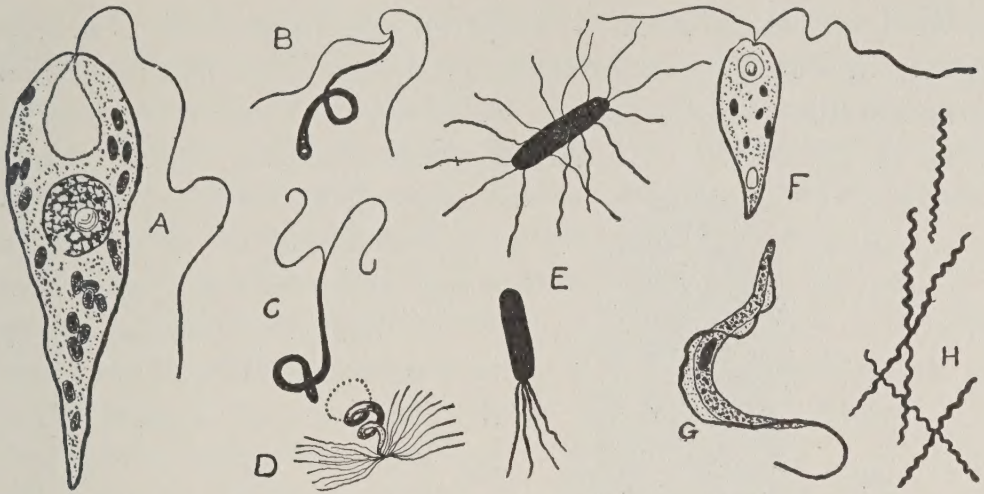


FIG. 50.—To illustrate the fact that organs of motion and motility are not exclusive animal characteristics. A, *Euglena*, a unicellular green alga. B, motile sperm of the *Chara*, one of the algæ. C, motile sperm of a moss. D, motile sperm of a fern. E, motile bacterial cells. F, a motile protozoan from stagnant water. G, a trypanosome. H, *Treponema*. A, B, C, D, E are plants or plant cells; F, G, H are protozoan cells. All of these cells are motile by means of flagella or cilia. (From Buchanan.)

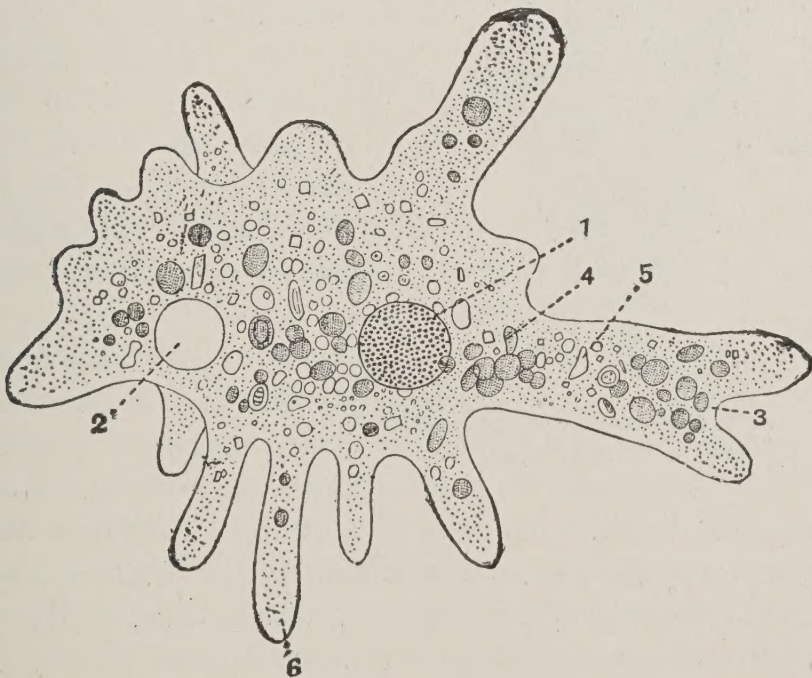


FIG. 51.—*Amoeba proteus*. (From Hegner, after Gruber.)

Although the cell unit is common to all life, there is a very great amount of variation in its specialization. Some one-celled organisms are very simple in structure, such as the bacillus of tuberculosis, while others are very complex, such as *Paramecium*.

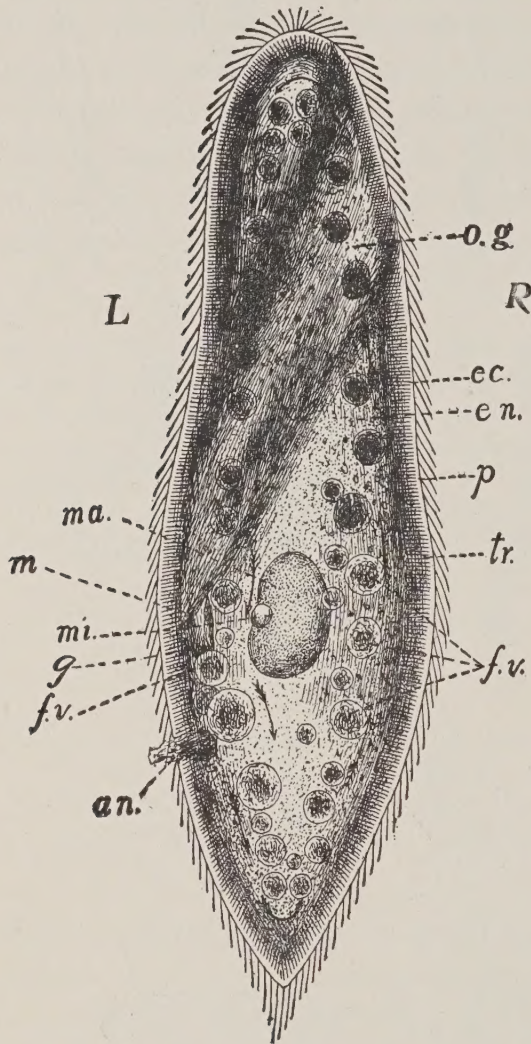


FIG. 52.—*Paramecium caudatum*. (From Hegner, after Jennings.)

Some cells are quite generalized in function, as egg and sperm cells, while others, such as muscle and nerve cells, are highly specialized. By function is meant the normal and special activities carried on by a cell, tissue, organ, or organism.

A specialized cell, as the term is used here, is one performing a very definite function or functions, and consequently likely to have a special structure or shape; whereas a generalized cell probably performs a number of functions and is less likely to be distinguished by any outstanding structure or shape.

One-celled animals and plants, such as *amœba* and yeast, are more generalized both as to structure and

function than is some one cell of a complex organism like the dog (except for the germ cells, which are generalized always). In *Amœba proteus*, no part of the cell is set aside strictly speaking to perform any certain function, such as digestion, excretion, or respiration. One can say that "special organs" for these

purposes are lacking, and yet all of these functions are carried on by *Amœba*. Although no organs or parts of organs are present as such, yet in a sense every part of this one-celled animal is the digestive system, every part is the respiratory system, every part is the reproductive system. *Amœba proteus* is indeed a highly generalized cell both in function and in structure.

In the higher metazoa, on the other hand, about the only remaining generalized cells are the egg and the sperm cells, and these are generalized only as to their function—their power to

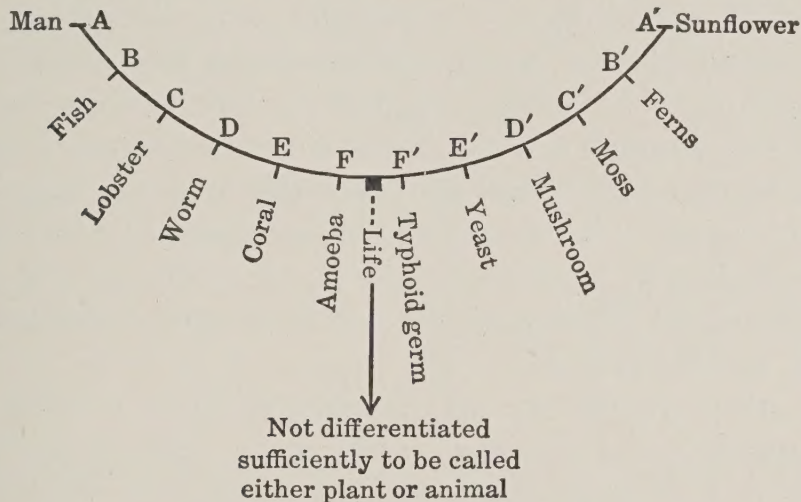


FIG. 53.

produce early in the life of the embryo all of the other cells of the body.

In the preceding paragraphs it has been assumed that one may readily distinguish plants from animals, and yet this is not always true. Anyone can distinguish the higher animals from the higher plants; and even the great majority of animals high and low in the scale of development from the great majority of plants high and low; yet a number of forms of microscopic life might be classed as either plant or animal. The accompanying drawing will illustrate.

It would not take a biologist to conclude that A represents the highest form of animal life, and that man greatly differs from A', one of the most highly developed species of plant life. One would not have to think twice to say that B is an animal and

B' a plant, or that *C* is an animal and *C'* is a plant, or even that *D* is an animal and *D'* is a plant. But one would require biological training to be able to prove that *E* is an animal and *E'* a plant, and would have to be well versed in biology to be sure that *F* is an animal and *F'* a plant. Even experts in protozoölogy and bacteriology would not say definitely whether *Euglena viridis* and *Spirochæta pellida* are animals or plants. They are either one or the other, or neither, depending upon what one accepts as the true plant and animal characteristics. A professor of bacteriology once said partly in a jest and partly in earnest, "Bacteria are animals now usually classed among the plants." Some of these forms of life have characters common to both plant and animal life, although most of the characters of bacteria are plant-like. A textbook of zoölogy dealing with the lowest forms of life may discuss some of the species that are listed in a textbook of botany dealing with the lowest plants. Good examples of species thus studied are *Euglena viridis* and the genera *Spirochæta*, *Peridinium*, and *Treponema*.

One can no longer say (1) that animals move and plants do not, because many animals do not move, such as corals and sponges; and some plants do, such as typhoid and cholera bacteria; (2) that plants are green and animals are not, because not all plants are green, such as mushrooms and toadstools; and some animals are green, such as some sea anemones and some hydras; (3) that animals use oxygen and plants do not, because all life uses oxygen; (4) that plants use carbon dioxide and animals do not, because many non-green plants, such as fungi, have no more use for carbon dioxide than do the birds or mammals; (5) one cannot even say that the plant cells have part of their cell walls made out of cellulose and that the animals do not, because many of the bacteria do not have the cellulose in their cell walls, at least so far as can be detected by methods now available.

It is probably true that if two or three of the above diagnostic characters are combined, one can determine that this species is not a plant and that species not an animal. The outstanding

fact remains, however, that in no one structure and in no one function can the lowest plants be distinguished from the lowest animals.

The accompanying diagram will illustrate what is believed to be the relationship and derivation of plant and animal life.

In the human body, and in all other mammals as well, there are, according to McGregor, only four fundamentally different kinds of somatic (body) cells—muscular, nervous, epithelial,

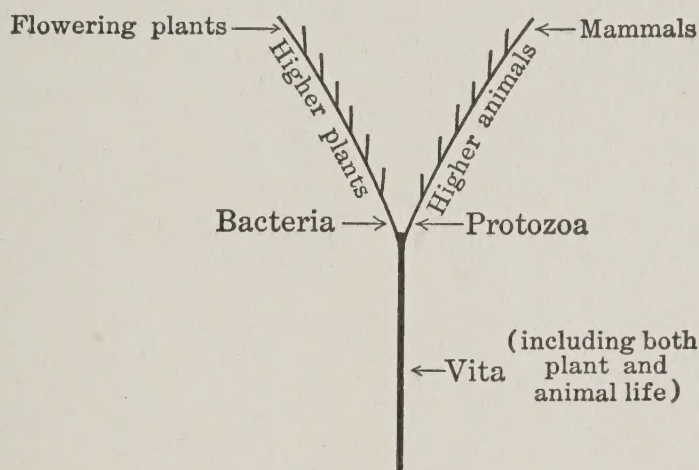


FIG. 54.—There are about 250,000 known living species of plants and about 500,000 known species of animals.

and connective. All other types of body cells, such as gland and bone cells, are just modifications of these four fundamental kinds.

The muscles of the adult human being comprise the largest part of the body, about forty-three per cent by weight.¹ In the very young child the proportion is still high, although reduced to about twenty-three per cent. The child is carrying about the equivalent of another person of his own size on his shoulders when compared with the load that the adult is carrying.

Apparently the sole function of the muscle cells is to contract and expand. Most of the muscle cells, and particularly those of the voluntary muscles, are long and slender, sometimes reaching a length of two inches in the human body.

¹ Terman, L. M., *Hygiene of the School Child*.

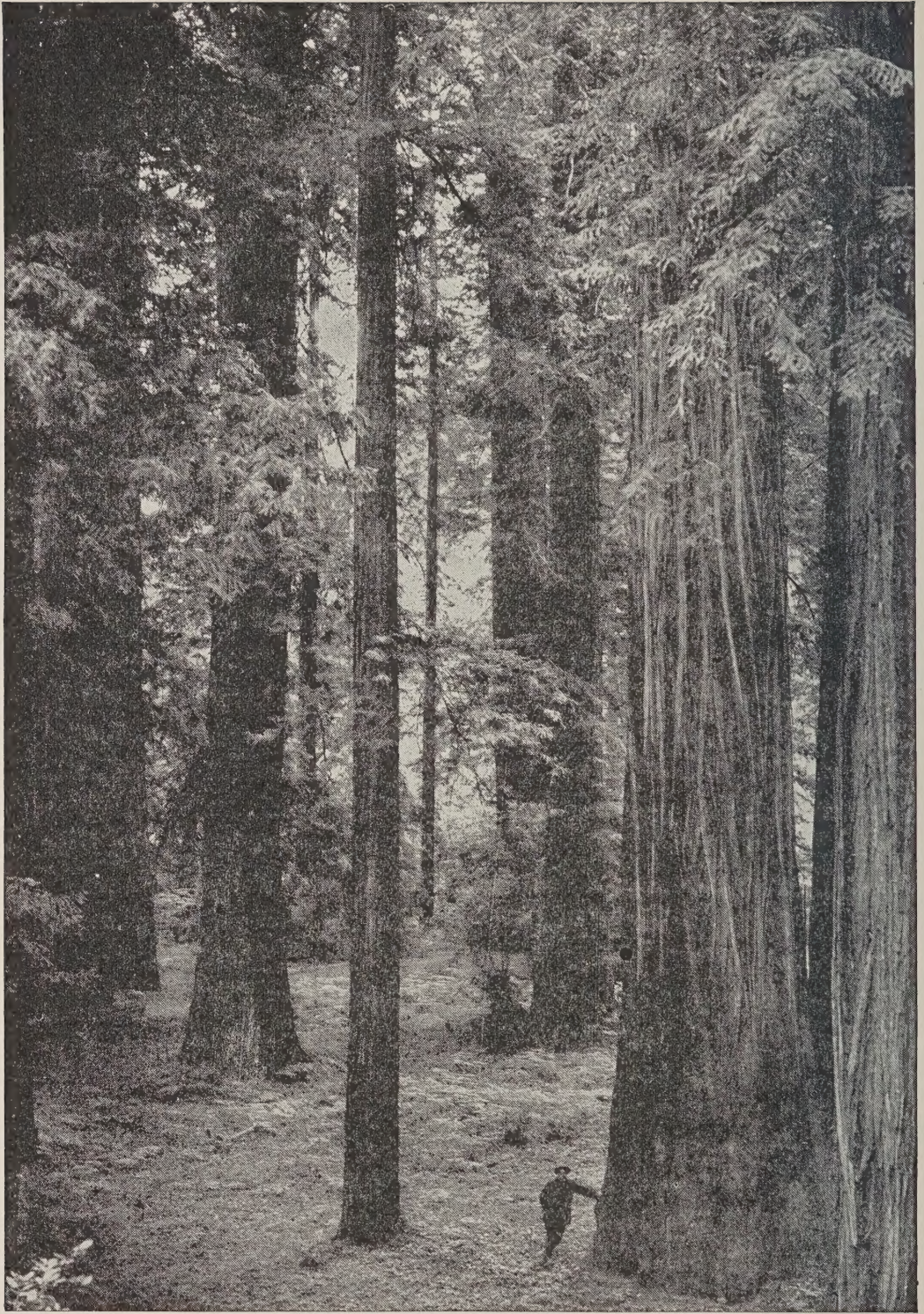


FIG. 55.—Giant Redwood trees, *Sequoia gigantea*, Humboldt County California. (From Campbell, photograph by courtesy of Save the Redwood League.)

Although the total weight of nerve cells is but little when compared with that of the muscle cells, yet they are so widely distributed that nearly every part of the body is served with nerve tissue except the nails, hair, blood, outer layers of the skin, and certain parts of the teeth. The nerve cell usually has a prominent center from which radiate a number of slender nerve fibers. The function of these cells seems to be limited to the receiving, transferring, and retaining of stimuli.

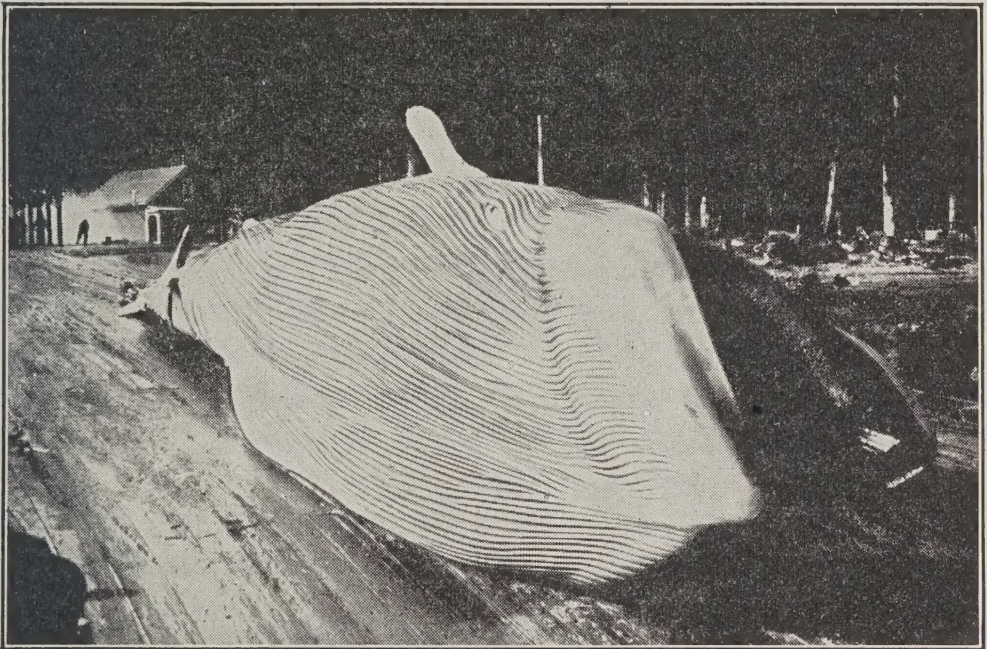


FIG. 56.—A giant *Sulphur bottom whale*. Contains many billions of cells of various kinds—muscular, nervous, epithelial, connective, and reproductive cells. (From the American Museum of Natural History.)

The epithelial cells of the body are found in several forms or modifications. Their chief functions are to protect and cover the body and to line the various bodily cavities, such as the alimentary canal, the lungs, and the bladder. The skin, mucous membrane, hair, feathers, horns, and scales are modified epithelial cells. The epithelial cells forming the skin are usually flattened and angular but fit together so tightly, that when united into a tissue, it is impossible for even small bacteria to find openings for penetration.

The connective cells, as the name would indicate, serve chiefly to unite other tissues of the body. These are found



FIG. 57.—The human tuberculosis germ, *Mycobacterium tuberculosis*, in sputum (x 1000). (From Buchanan.)

between muscle cells and between the skin and the muscles of the body. The bone matrix is largely connective tissue and forms much of the connective tissue of the human body. Except for the bone matrix the volume of this tissue in the body is not large.

The multiplication of cells to form tissues involves a complex process called *mitosis* or *cell division*. A large amount of work on mitosis has been done by a host of investigators and the details of this process

are well known and can be readily demonstrated by means of a few slides under the microscope.

All body (somatic) cells are either growing, resting, or undergoing the process of cell division. In a typical animal cell just

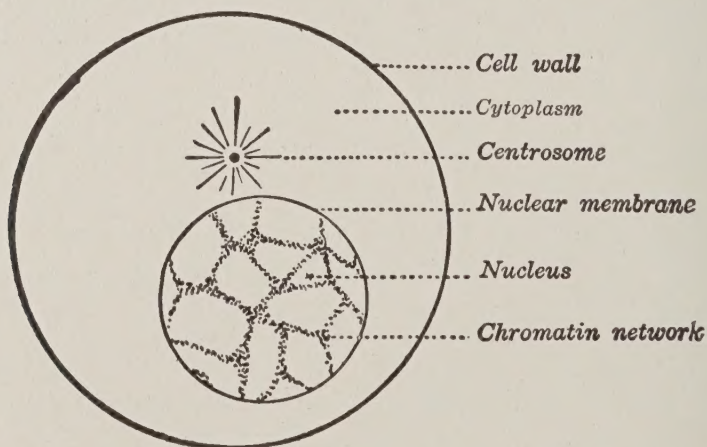


FIG. 58.—Diagram of a typical cell. (From Walter.)

ready to start the process of cell division can be seen, if stained properly, a nucleus, a nuclear membrane, a centrosome, the

cell wall, the cytoplasm, and sometimes chromatin granules or network.

At the center of the cell pictured in Figure 58 is the *nucleus* surrounded by a *nuclear membrane*. The *cytoplasm* is the substance

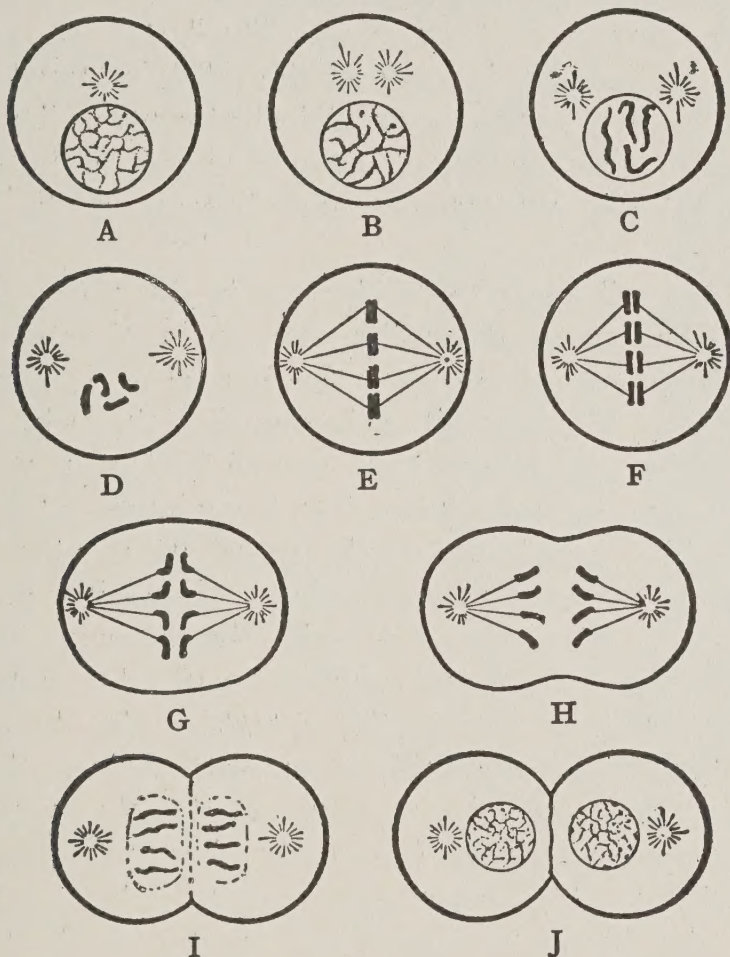


FIG. 59.—Diagrams illustrating mitosis. A, resting cell; B, beginning prophase; C, early prophase; D, prophase; E, end of prophase; F, metaphase; G, beginning anaphase; H, anaphase; I, beginning telophase; J, end of telophase. (From Walter, after Boveri.)

between the nuclear membrane and the cell wall. Just outside the nucleus and lying within the cytoplasm is the *centrosome*. The *chromatin granules* (network) are found inside the nucleus. All of these parts, together with others of no great importance in this discussion, form the living substance called *protoplasm*.

The function of the cell wall is to enclose the cell; the function of the nuclear membrane to enclose the nucleus. The nucleus itself is usually regarded as the most significant part of the cell since a cell deprived of it cannot live long. The chromatin granules are very important because they are the stuff out of which the chromosomes are made. The latter are extremely important because the heritage of the cell is centered in them and because they exercise a physiological control. The centrosome is also very important since it seems to initiate and later control the arrangement and division of the chromosomes.

Before the cell starts to divide, it is in the *resting stage* and all of the parts are usually visible. The first noticeable development in the process of mitosis is the division of the centrosome into two parts. This is called the beginning of the early *prophase*. Very soon the centrosomes have moved farther apart and the chromatin granules have united into larger units, later forming long skein-like threads and finally a definite number of chromosomes. At the end of the prophase, the nuclear membrane has dissolved and vanished and the chromosomes lie at the center of the cell on fibers connected with the centrosomes. In the next stage of mitosis, the *metaphase*, the chromosomes split lengthwise, and when this is complete we have the beginning of the third stage, the *anaphase*. During the anaphase the half-chromosomes separate from each other and move toward their respective poles, the centrosome centers. In this phase the cell wall also begins to "pinch in." In the fourth stage, the *telophase*, the chromosomes grow to full size, the cell is divided into two equal parts, and the nuclear membrane begins to reappear. At the end of the telophase the chromosomes have broken up into chromatin granules or network, and two daughter cells have been formed which are just like the original parent cell except for size. These two cells now represent the *growing stage* in the life of the cell, that is, they enlarge themselves if furnished with food and other favorable conditions.

The important facts to remember in this process of mitosis

are that two cells of equal size, the daughter cells, are formed from one, the parent or mother cell, and that these cells are just alike since each one inherited just what the other did. As stated, if these cells are furnished with the proper food and supplied with the right kind and amount of oxygen, and if the wastes are properly eliminated, we have that familiar thing which is universally called *growth*. Perhaps there is no more interesting phenomenon and certainly none more satisfying than this process of growth—whether it be in clover, corn, chickens, kittens, or children.

Occasionally cells grow into tissues by a process called *amitosis*, a process in which the cells “pinch” in two without undergoing the complex process of mitosis, but when observed carefully such cells seem usually to be either unhealthy or old. They do not have the power of continuing their kind indefinitely as do those cells which reproduce by mitosis. Cancerous growths are thought to be entirely amitotic.

Before the day of the compound microscope no one knew just how living things grew. As a matter of fact mitosis was clearly understood only toward the end of the nineteenth century. Perhaps the most common conception was that the skin of the body stretched for some reason, and the larger cavity thus created

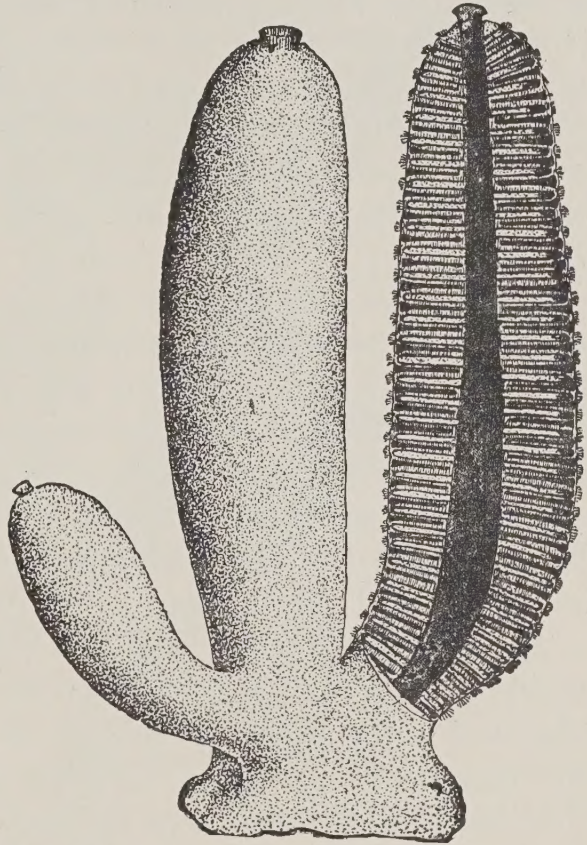


FIG. 60.—A simple sponge, *Sycon*. The right hand member of the colony is shown in longitudinal section. (From Hegner, after Parker and Haswell.)

was filled in some unknown way similar to the inflation of a rubber balloon.

In all living things, a building-up process and a tearing-down process are going on all the time. The tearing-down process is known as *katabolism*, whereas the building-up process is known as *anabolism*. Both processes together are known as *metabolism*. The elderly person who shows distinctly that he is losing weight and energy year by year is a good example of a preponderance of katabolism; whereas the child who is gaining weight year by year illustrates a preponderance of anabolism. In the middle-aged adult the processes of anabolism and katabolism are about balanced.

It should be stated that in the lower forms of both plant and animal life, the process of mitosis is greatly varied and simplified, yet the essential features remain the same. The chromosomes often differ in shape and in number among different species. In some species there are only two chromosomes to a cell, and again in other species there may be several hundred. The human being has (probably) forty-eight chromosomes in all healthy somatic (body) cells.

The rapidity of cell division has been for years an interesting question. It is certain that every form of life has a rate of its own, but in the human being the rate is modified by the race, the age, and the health of the individual. There is an old belief that the cells of our bodies are entirely replaced every seven years. If this were true, it would be an easy mathematical problem to determine the approximate rapidity of cell division, for we already know about how many cells there are in an adult human being, and we know about the size of the average cells; but unfortunately, or perhaps fortunately, the problem is not to be so easily solved, for the belief that the cells change every seven years is a pure myth.

It is now well known that the one-year-old child has just as many brain cells as he will have when seventy years old—in fact the same brain cells; whereas the epithelial cells of the palms of the hand and soles of the feet change in less than a

year's time. The other skin cells change very rapidly also. The other cells of the body doubtless fall between these two extremes. Because of this very uneven replacement of the different cells of

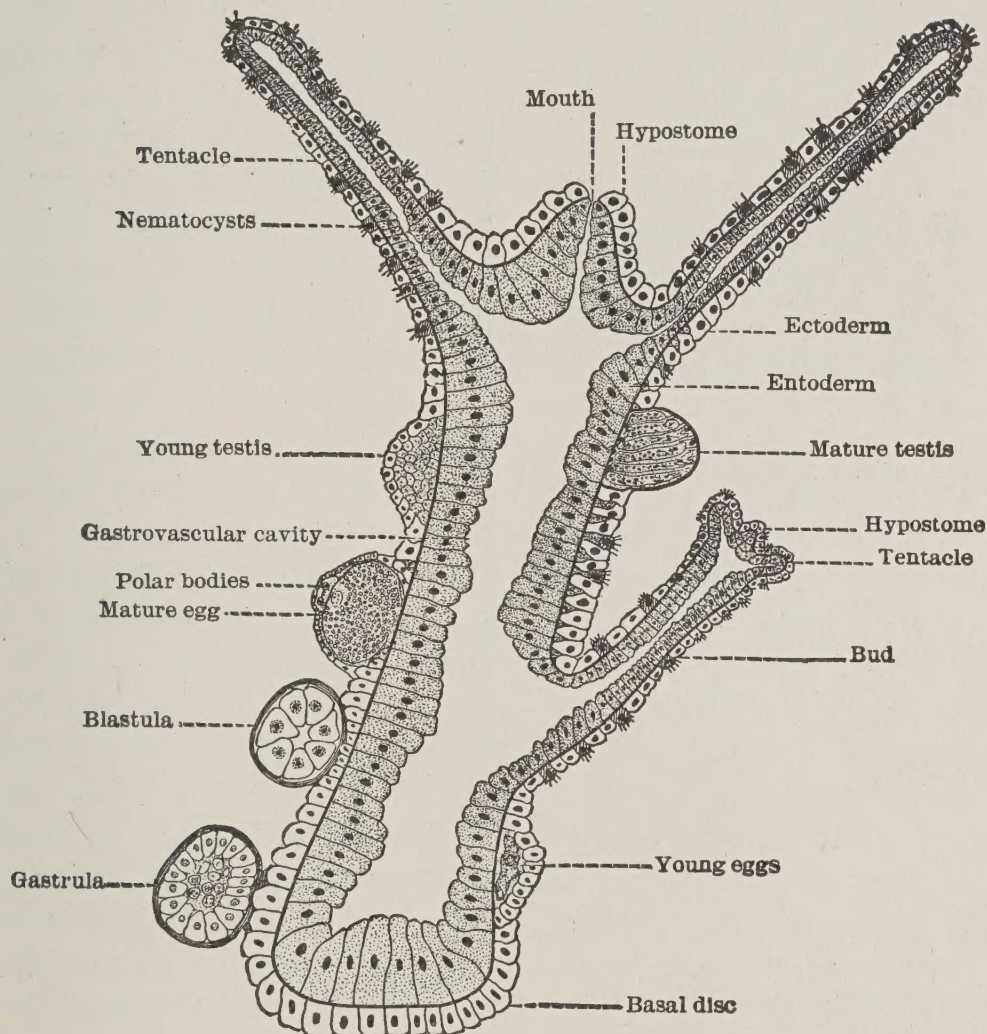


FIG. 61.—A longitudinal section of *Hydra*. Not all the structures shown occur on one animal at the same time. (From Hegner.)

the body, it is impossible to give even a fair estimate of the average rapidity of mitosis.

Man is one of the slowest growing animals, and it therefore seems fair to assume that the replacement of old cells by new ones is also very slow. In the course of twenty years the average human being gains in weight less than one hundred and fifty

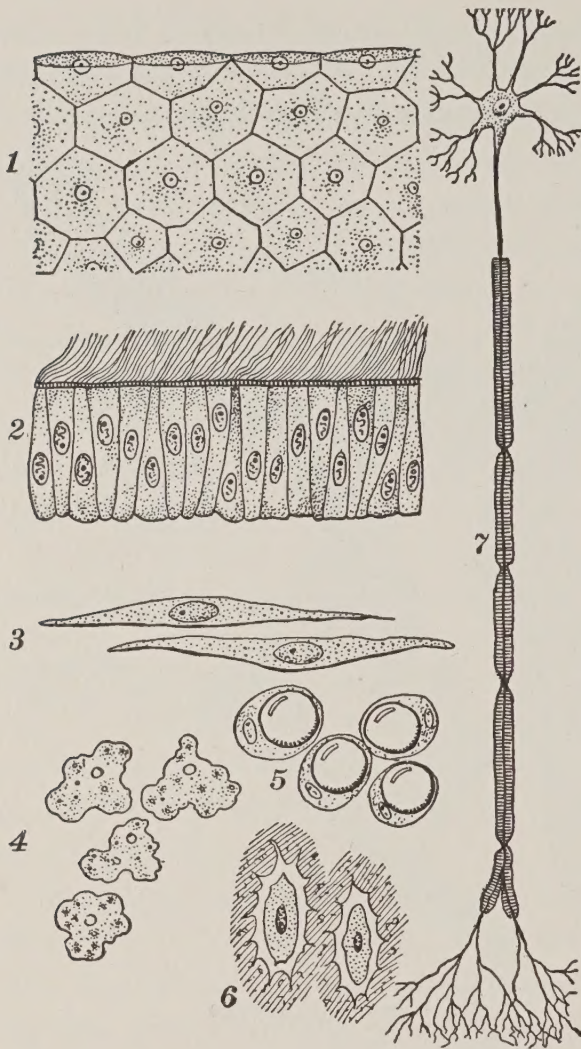


FIG. 62.—Various kinds of animal cells. 1, from lining of cavity of abdomen in man; 2, columnar epithelial cells, in air passages; 3, muscle cells, unstriated, from wall of intestine; 4, shapeless cells, like amoeba or white blood corpuscles; 5, cells containing fat globules, as in adipose tissue; 6, bone cells surrounded by hard deposits of limy material; 7, a nerve cell, or *neuron* (a, the cell body with its branching outgrowths, or *dendrites*; b, the longest outgrowth, the *axon*, ending in c, the terminal branches). (From Gruenberg's *Biology and Human Life*, by permission of Ginn and Company, publishers.)

pounds; whereas the pig gains as much at the end of eight months,—and this in spite of the fact that the pig at birth is only about one-half the size of the babe. Nearly all of the great momentum of growth is expended in the embryonic period. Before birth the human embryo increases in size over a billion times—after birth only about twenty times.

Although the cells of the pig grow much more rapidly than those of the human being, there are many other forms which far outstrip the pig. Probably the most rapidly growing organism under conditions favorable for growth are the bacteria and protozoa. When conditions seem to be just right, these forms have been known to divide every fifteen minutes and to keep this up for a number of hours. While a rate of division throughout the year even one

tenth as fast on the average is impossible, yet for short periods of time a very rapid pace is often set as in the case of the bacteria of certain diseases, such as severe colds and pneumonia. Since these disease germs multiply often at the rate of twice an hour, it is possible for one to feel thoroughly well at night when one goes to bed harboring only a few thousand germs, and in the morning to be very sick from harboring many millions.

To prove this to one's own satisfaction one does not need to experiment with illness; it is necessary only to work a simple problem in mathematics. Starting with one cold germ dividing at the rate of once every half-hour, how many cold germs will result in twenty-four hours if this rate of division is continued? The answer is something over two hundred and eighty-one trillion—more than enough germs to kill an army. Of course cell division probably never actually happens at even one-twentieth of this rate, since the body, in various ways, kills off a large proportion of the germs before they have a chance to divide and form daughter cells.

Since some diseases, such as pneumonia, can develop in a healthy body, it behooves one not only to keep the body strong to avoid other diseases, but also to dodge and avoid infection whenever possible. This is the chief reason why sanitary measures in the schoolroom and elsewhere are so important. Good health is largely a matter of good inheritance, proper exercise, good food, fresh air, and a good mental condition, *plus* the avoidance of infection.

When a number of tissues are united in such a way as to carry on certain important functions of the body, an *organ* is formed, such as the heart, lungs, stomach, kidneys, etc. Often all of the four principal kinds of cells are present in an organ. For example, in the heart are found muscular, nervous, epithelial, and connective tissues. This is also true of the stomach and of many other organs.

When a number of organs are so united or integrated as to carry on all the functions necessary for the continuance of life, we have an *organism*. Any unit of life, whether large or small,

is an organism that is capable of irritability, contractility, metabolism, growth, and reproduction.

Very briefly, then, we can say that *cells* form *tissues*, tissues form *organs*, and organs form *organisms*. The smallest organisms



FIG. 63.—Grafts, types of asexual reproduction. A bud or twig of one plant is made to grow by means of the nourishment supplied by the root or stem of another plant. The root or stem supplying the nourishment is called the *stock*; the bud or twig grafted on the stock is called the *scion*. The figures show stem, bud, and root grafts. (From Gruenberg's *Biology and Human Life*, by permission of Ginn and Company, publishers.)

obviously have only one cell, whereas the largest have many thousands of millions of cells. In the human being it has been estimated that there are about four hundred billion cells. Neu-

rologists estimate that there are at least 12,000,000,000 nerve cells in the human brain and spinal cord.

Within the past thirty years it has been shown that to understand life one must be acquainted with the structure and the functions of the cell. The most interesting phenomenon of all life—growth—is understandable only in the degree that one understands the cell. The physical growth of the child is essentially the same process as that found in all other forms of life.

QUESTIONS

1. Why do you think the one-celled plants and animals appeared on earth before the many-celled plants and animals?

2. Can you suggest a scientific reason why it would be almost impossible to find or to grow a redwood tree taller than those now growing in California?

3. Why do you think the cells in some parts of our bodies are worn out and replaced much faster than in other parts?

4. Why do you think amitosis takes place quite often in pathogenic or old tissues?

5. How would you suggest that one could prove that the brain in mankind is essentially an organ for thinking, rather than primarily for some other purpose?

6. Why do you think growth is accomplished in the child in essentially the same manner as in the other animals and in the plants?

7. Why is it an advantage to the human race that the mitotic process is slower in the child than in most other animals?

8. How closely related is the size of a child to the rapidity of the mitotic process?

9. At what stage of school education should the facts of cell structure and function be taught?

10. In what ways if any would a knowledge of these facts help one to live better?

CHAPTER XVII

ONE-CELLED VERSUS MANY-CELLED ANIMALS

All animals, including the human species, begin life as one-celled organisms—Probable reasons for the origin of the many-celled animals—Advantages possessed by many-celled animals—The two chief kinds of reproduction, asexual and sexual—Male, female, and body cells—Human cells compared with those of other animals.

It is sometimes said that the amœba is the simplest type of life in existence, but this is not true. There are hundreds of species of bacteria, not to mention other kinds of protophytes, that are simpler than the amœba.

However, if one states that the amœba is as simple a form of unquestioned *animal* life as exists, one would be likely to have many supporters. It should be pointed out, though, that there are several outstanding protozoölogists who question this oft-repeated generalization of the extreme simplicity of the *Rhizopoda*, to which the amœba belongs, maintaining that other groups are still simpler.

Setting aside technical discussion of the relative simplicity of the various kinds of protozoa, we shall assume in this chapter that the amœba represents the simplest type of animal life, since the opposition has as yet not been able to convince the majority of biologists to the contrary. The old favorite, *Amœba proteus*, found illustrated in many texts, will serve our case well.

By a simple animal we mean one that has few specialized structures which in turn have specialized functions, and by a complex animal one that has many specialized structures and functions. If we examine the amœba carefully in the light of such a definition, we find that it is a very simple organism, having almost no specialized parts or functions.

Even definite shape, the one thing almost universally characteristic of living organisms, is not to be found in several species of amoeba, including *Amœba proteus*. In form, this tiny animal is sometimes very nearly ball-shaped, again flattened, elongated, or with many projections from its body, called pseudopods. If for a ten-minute period, one attempts to draw the various shapes one amoeba assumes in that time, one will be amazed. A drawing pencil and tablet are hardly the right instruments for the occasion; a motion-picture camera would be preferable.

Locomotion in an animal is usually accomplished, if at all, by a definite part of the body of an animal, but such is not the case in certain amœbæ. Any part of the body may be found protruding in the form of false feet or pseudopodia. Digestion, respiration, excretion, and almost all other functions, it can be demonstrated, are performed by no one particular part of the organism, but are the functions of most of the parts of the cell taken as a whole.

Expressing it in another way we may say that the amoeba has no feet, yet all of its body may become feet; it has no stomach or digestive system, but almost any part of its body may act in that capacity; it has no lungs, but all of its surface may act as lungs; and so on, including almost all of the functions of any animal.

The amoeba is somewhat analogous to a cross-roads country store specializing in nothing, but carrying something of everything. The body of a metazoan (or metaphyton, if a plant) is somewhat analogous to a city with many stores, each of which is almost certain to specialize in one particular field.

The difference, then, between a generalized animal and a highly specialized one is not so much in what they do as how and with what they do it. If an organism is to develop far in any particular direction, certain cells or organs must be set aside to carry on that particular function. The key to advancement in any given direction is specialization. Now it does not follow that the animals of a highly evolved group will have all of their cells and organs highly specialized. Some parts will be more

highly developed and specialized than others, but at least some parts are likely to be more highly specialized than the corresponding cells of a more lowly group of animals.

Both the protozoa and metazoa grow and reproduce their kind, and here is their greatest similarity; and here also is the beginning of the greatest difference.

One may often hear that non-organic things grow also, but this is a very superficial statement. To be sure, if certain crystals are time after time immersed in the mother liquid and allowed to cool, they may become larger and larger; or if in their original location, where water containing the dissolved crystal material may drip upon the crystals, they may become larger. This is not true growth; it is increased in size by accretion rather than by re-arrangement and enlargement of its parts,—a process called intussusception.

True growth and reproduction, then, are characteristic only of living things, but the method of reproduction differs greatly in different species. There is a particularly striking difference between the method of reproduction of a typical protozoan when contrasted with a typical metazoan. In a typical protozoan, reproduction is almost entirely by an *asexual* method called *fission*; whereas in most of the metazoa, particularly the higher orders, reproduction is usually accomplished by the *sexual* process, which involves the union of elements from a male and a female.

Probably next to the amœba, the paramecium is the most widely known protozoan; and since it has a very definite shape, it can be used as typifying the protozoa. Scientists who have studied the paramecium in detail find that it reproduces for hundreds, even thousands of times, by simple transverse fission, and then it may undergo conjugation with another paramecium. This transverse fission has been found to be a simplified form of mitosis, so typical of the somatic (body) cells of the higher species. (See Chap. XVI.)

Asexual reproduction, it seems, has both its advantages and its disadvantages. The particular advantage is that the asexual process is much simpler than the sexual process, much safer, and

much more rapid, as a general rule. The complete sexual process in plants and animals usually takes a number of days, weeks, or even months, while the asexual process of fission in a protozoan may be carried through from beginning to end in less than a half-hour under optimal conditions. If one is careful to keep the food plentiful and the water in good condition, a million descendants from one paramecium can be raised in a very few weeks; whereas many months and usually many years would be needed to raise as many descendants from an animal which uses the sexual process.

As stated in another chapter (see Chap. XIX), all the progeny from one self-fertilized or unfertilized individual are known as a *pure line*. It has further been emphasized that variation within the pure line is limited. That there would be very little variation among the descendants of an individual that reproduces by the process of fission is quite evident and readily understood. It can all be summed up by saying that such individuals have little chance to vary, since they have exactly the same inheritance, except as temporarily modified by environmental conditions, such as a scant amount of food or intense heat or cold.

The asexual process, indeed, is an almost perfect way of insuring in the shortest possible time the greatest possible number of offspring having the greatest possible similarity to one another. Since the entire animal is made up of but one cell, it is obvious that there can be no differentiation into somatic and germinal cells, the latter group including the egg cells and sperm cells. In the protozoa the cell is both germinal and somatic in nature; and of course whatever happens to it is transmitted to the next generation, since the next generation is in reality only this generation divided into two parts called individuals. Thus in one way a protozoan is immortal.

It can be readily seen, then, that in only the metazoa can we find differentiated cells, some of which are for the purpose of reproduction and the others for the purpose of carrying on other activities of the body. In the metazoa the germinal and somatic cells are almost if not completely independent of each other, ex-

cept for food; whereas in the protozoa they are one and the same thing. This will be an important point to remember when we come to discuss the "inheritance of acquired characters" (Chap. XXIV).

It is clear, also, that in the protozoa there are no such things as male and female cells. Only animals that have marked differentiation of cells have sperm and egg cells. Even when there is a union or, more correctly, a conjugation, of two protozoa as in *Paramecium caudatum*, there is a like and equal exchange of materials. This is not sexual reproduction in the true sense.

The sex cells of the metazoa on the contrary usually vary greatly, particularly in size and motility. That the male and female germ cells carry an equal amount of inheritance is now well established, but it is equally well known that the amount and kind of cytoplasm surrounding them differs greatly. As stated in Chapter XIX, the male cell is often not one ten-thousandth the size of the female cell of the same species, and the latter cell is seldom motile. However, the motility of the male cell is well established for almost all species of metazoa.

If one examines a book picturing the many families and genera of protozoa, one is amazed at their exceedingly variable shapes and sizes. In the great majority of them, no good reason can be given for the shape. It seems to have little value in adapting the animal to the environment, except, perhaps, when it makes possible a hard covering which enables the individuals of the species to dry up as spores and thus pass through unfavorable seasons.

In most of the metazoa, on the other hand, the forms of the various parts harmonize closely with the functions of these parts. The muscle cells of man are long and slender, enabling them to contract and expand, the skin cells are flat, and thus cover a given area with the least amount of material possible; the nerve cells are slender and much branched, thus allowing them to spread and connect with one another in many different combinations; the bone cells are covered with a solid secretion that makes for rigidity; and so on throughout the entire body.

Extreme differentiation in cells is not to be found in the lower metazoa, but rather only in the higher types. The cells of a large sponge, although they are of several types, do not vary nearly so much as do those of a cat, for example. In the latter animal are found cells not present at all in the former, such as those forming the heart and the blood vessels.

In all of the vertebrates the sexes are separate. Nor is there any record of reproduction by the asexual process. Sexual reproduction is the one method of reproduction in all of the higher orders.

Many theories have been advanced to explain why, in the higher animals, there are two distinct sexes. Although this problem is far from completely solved, one of the answers is that increased vigor in the species is the result. It is well known that excessive inbreeding, which would be similar to but not identical with having both sexes in one organism, is almost sure to result in physical deterioration, in many species at least. It would appear however that the chief reason for the existence of two sexes is that the chance for variation is greatly increased, and in the long run this is a most important factor in keeping a species adapted to its environment.

An illustration of the use of asexual methods of reproduction is found in the methods employed by nurserymen in propagating fruit trees. From the desired "parent" trees slips called "scions" are cut, and these are grafted on to the "stock" of young trees of the same species that have been grown from seeds and are called "seedlings." Care is taken to remove all the buds from the seedling so that all subsequent growth will represent the stock from which the scion has been cut. By this process the exact variety desired can be secured one hundred per cent of the time; whereas the process of merely planting its seed would seldom produce the desired variety because of the variation that sexual reproduction is almost certain to bring about. A Jonathan apple scion grafted on to a Ben Davis stock will always produce Jonathan apples, because it is never given a chance to produce anything else. Jonathans have all come from one original tree,

directly or indirectly. In a sense, all Jonathan trees are still in the first generation and will remain so as long as the variety is propagated by grafting.

Grape vines and sugar cane are also often reproduced from slips or cuttings. In each case the plants produced come true to

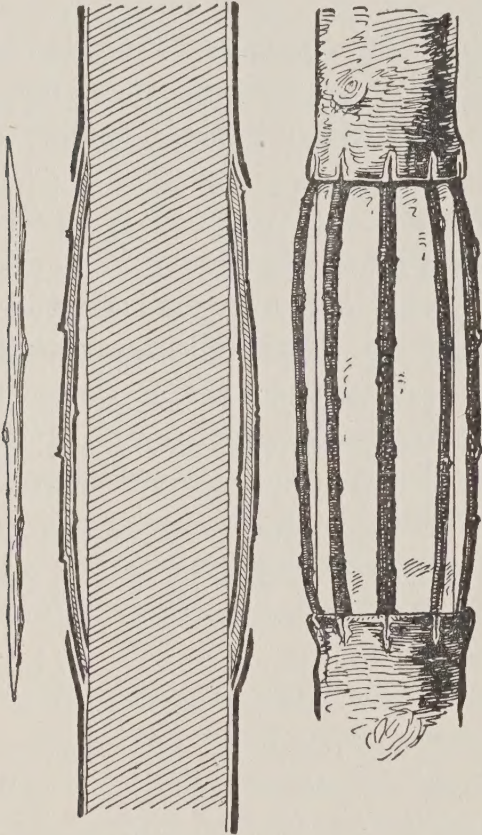


FIG. 64.—*Bridge grafting.* A type of asexual reproduction employed by nurserymen. (From Gruenberg's *Biology and Human Life*, by permission of Ginn and Company, publishers.)

type because no chance has been given to vary the germinal make-up, a thing which is possible under the sexual process.

In the animal realm, too, we sometimes find both the asexual and sexual processes used by one species. A good example is supplied by some planaria, which break off a piece of the posterior end from time to time and this fragment develops into a fully mature individual. The planaria also lay a great abundance of fertilized eggs. Hydra reproduce both sexually and by forming buds, asexually.

A very peculiar method of reproduction occasionally found in animals is called *parthenogenesis*. This simply means that reproduction takes place without the fertilization

of the egg cell by the sperm cell. The common bee is a good example. Here we find that the female bees, the queen and the workers, are the result of fertilized eggs, but the drone or male bee develops from an unfertilized egg. The particular advantage of such a process is difficult to imagine.

One thing common to both the protozoa and metazoa is that

both of them start as one-celled animals, although of course the latter very quickly lose this trait. It is natural to ask, as thousands have done, why or how did the metazoa get started? Why do the cells "stick together," so to speak, in the metazoa and not in the protozoa? Only a speculative answer can be given and this answer can cover only a few species that live in the water. If a species found in the water is motile and has flagella or cilia, it is easy to see that a second cell attached behind the first cell would offer very little additional resistance; whereas it would have just twice the power for locomotion that the one cell has. In some cases this increased motility would mean that a larger area of food supply could be covered than if the cell were alone. Again there might on certain occasions be greater safety from enemies because of this increased speed or because of the increased size.

Just how and why the first two cells stuck together we do not know, but that they did is certainly demonstrated by every living thing that is visible to the unaided eye. It should be pointed out again that there is little doubt that all life originated in the one-celled condition, and most biologists who are qualified to speak say that it originated in the water.

Reproduction in the protozoa can take place at any time after the organism reaches maturity provided the surroundings are favorable in respect to temperature, moisture, and food. In the metazoa, reproduction takes place only after the organism has increased many times in size and after a certain physiological maturity has been reached. Of course this varies greatly even in one order of mammals. In man the power of reproduction begins rather early in life with certain peoples of the tropics, but much later among the Northern races. If an average is given for all races, perhaps twelve years for the female and fourteen years for the male would be very nearly right.

In summarizing this chapter we find that there are two distinct types of reproduction, the asexual and the sexual. In the former we find several distinct varieties. For the lower animals and plants, the asexual process seems as a general rule to be the

more common, whereas in the higher animals the sexual process is the only method and in the higher plants it is the more common method, although here both types of reproduction are often possible. Again, in the lower forms of life, both sexes may be found in the same individual; whereas, in the higher animal species, the sexes are normally always separate.

QUESTIONS

1. It is commonly believed by most biologists that species in the beginning had only one cell. Can you advance any evidence against this theory?
2. All individuals of all species now apparently start from one cell. Can you suggest good reasons for this?
3. Can you think of reasons, other than those given in the text, why many-celled organisms would have advantages over one-celled organisms? If so, name them.
4. Name twenty plants that ordinarily reproduce asexually.
5. What advantages can you name in favor of the asexual method of reproduction? What disadvantages?
6. Why are muscle and nerve cells considered highly specialized cells?
7. In what way is it correct to say that the egg cell is generalized? Is specialized?
8. How far should a teacher go in explaining asexual and sexual reproduction to children in the elementary grades? In the junior high school? In the senior high school?

CHAPTER XVIII

THE EMBRYOLOGICAL RECORD

The development of the egg before birth or hatching—The method of formation of the three germ layers of the embryo from which all the organs and parts of the body are formed—The child's development before birth—Recapitulation theories of the past and present—What is true about mental recapitulation?—Application of embryonic facts and laws to the teacher's problems.

Embryology, the department of biological science which deals with the early stages of the life of an organism, began to be a definite body of knowledge with Marcello Malpighi, who published his observations in 1672. As a recognized division of biology, embryology is of much later date, having been placed upon a scientific basis by Karl von Baer. It is impossible, however, to designate the first person who studied embryonic life and the exact time when the first observations were made. Even Aristotle, over three centuries before the Christian era, made noteworthy observations on the development of the hen's egg. In the two and a half centuries since Malpighi, an enormous number of facts have been discovered about the beginnings of life in individual members of various species. Many forms of embryonic development, representative of all the groups of the animal kingdom, have become well understood as to their manner of development, and now there remains little doubt about the important steps in the embryology of man.

Embryology is especially significant in that it furnishes important clues to the past history of animals. Every organism, no matter how complex, begins its existence as a single cell; and between that simple state and the fully formed structures of adult life many gradations are exhibited. The fact that all unincubated and unfertilized eggs of vertebrates as well as other

animals, regardless of size and condition, are in reality single cells, was not demonstrated until 1861, when Gegenbaur proved it. About 1865 the same thing was found to be true of the sperm, or male, cells.

With the aid of the microscope it has also been demonstrated that upon the union of an egg and sperm of any given species, definite embryonic changes take place. The early phases of em-

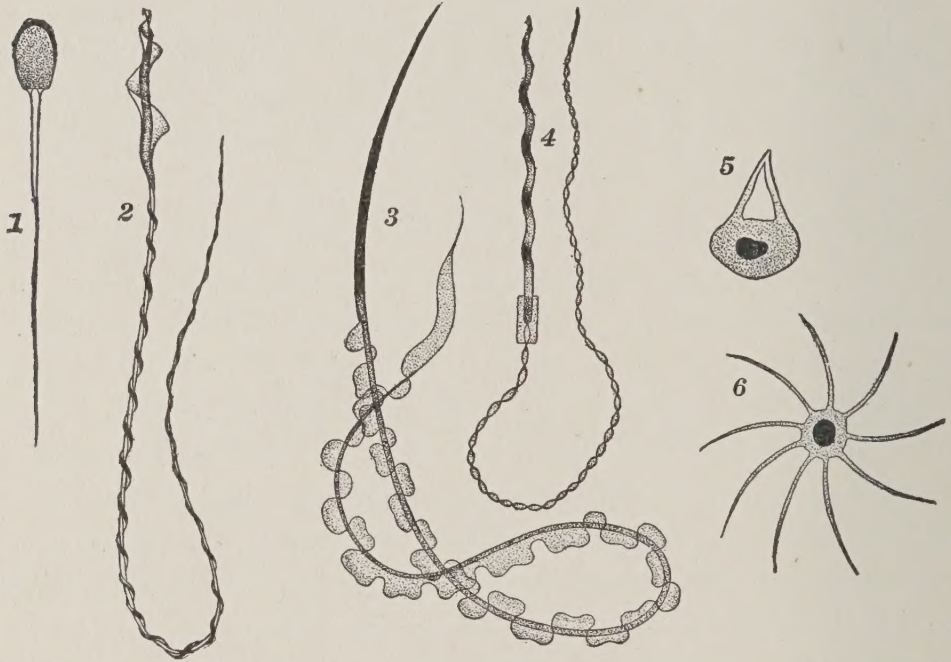


FIG. 65.—*Sperm cells of animals* (very highly magnified). 1, pig; 2, bird; 3, salamander; 4, ray; 5, threadworm (*ascaris*); 6, lobster. (From Gruenberg's *Biology and Human Life*, by permission of Ginn and Company, publishers.)

bryology, those which are most important from the teacher's standpoint, will now be explained.

The typical ovum or egg cell is round, immotile, and large when compared with the sperm cell, which is always minute, of varying shapes, and usually exceedingly motile. The egg cell is often more than a thousand times as large as the sperm cell of the same species, although each carries an equal amount of the inheritance fund, and each transmits to the next generation one half of the inherited traits.

The fertilization of the egg by the sperm cell does two things: first, a physico-chemical stimulus is given to the egg, causing it to continue its interrupted development; and second, as indicated, one half of the inheritance fund is brought in by the sperm cell. The fertilization of the egg by the sperm cell in the lower vertebrates, up to and including the amphibia, is usually accomplished outside of the body of the female; whereas in the reptiles, birds, and mammals, it takes place inside the body. Because of the greater safety of eggs fertilized inside the body, fewer eggs are produced by the reptiles, birds, and mammals than by the amphibia and fishes.

Upon union of the egg and sperm cells, the two gradually fuse, nuclei and all, so that we again have a one-celled form. Under normal conditions, soon after the egg cell is fertilized it begins to divide by the process of mitosis. In the lower forms of life the progress of development is often very unsteady because of variable temperatures. In the birds and mammals, mitosis is much steadier because of a constant temperature—so steady, indeed, that if one knows the number of hours that the embryo chick, for example, has been incubating, one can predict rather exactly the stage of development which, upon opening the shell, the embryo will be found to have reached. Under controlled conditions of the laboratory, almost the same results can be obtained in the cold-blooded or bloodless forms as in warm-blooded animals in which the fertilized eggs are developed within the body.

Since the material is much more abundant and since much more work has been done on forms of life that hatch instead of being born, we shall study the former chiefly.

Frogs' eggs are of good size, are easily obtained, and will serve as good material for an initial study of the embryonic processes.

An examination of a frog's egg shows that it has a well-marked polarity and that it is radially symmetrical about its chief axis. The animal pole (dorsal side) is covered by a thin but dense and dark pigment, while the vegetative pole (ventral side) contains a large amount of yolk. If free in the water, the pigmented area

which is lighter in weight will be on top, because the specific gravity of the vegetative pole is greater.

Since there are usually thousands of sperm cells ready to enter each frog's egg, it is obvious that some way must be provided to keep more than one from uniting with the nucleus of each egg.

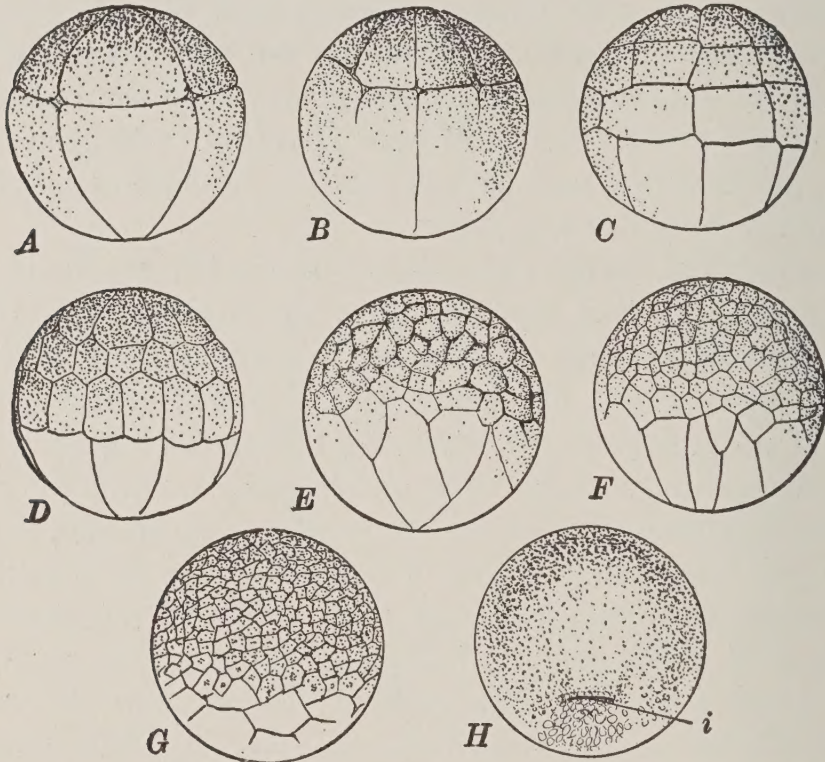


FIG. 66.—Cleavage of the frog's egg. (After Morgan.) Animal pole upward in all figures. *A*, eight cells. *B*, twelve cells becoming sixteen. *C*, thirty-two cells. *D*, forty-eight cells, more regular than usual. *E*, *F*, posterior and anterior views of about the 128-cell stage. *G*, late cleavage or early blastula. *H*, commencement of gastrulization (cell outlines indicated only in region below the invaginating groove). *i*, beginning of invagination. (From Galloway and Welch's *Textbook of Zoölogy*, published by P. Blakiston's Son & Co., Inc., Philadelphia.)

Almost immediately after the first sperm enters, the chemical nature of the cortex of the egg cell changes so that it is not easy for others to enter; and as soon as the sperm has progressed well toward the center, the maturation process in the egg nucleus is completed, followed closely by the throwing off of the second polar body. The detailed process of maturation will be given in

a later chapter concerned with heredity, but it is enough to say here that in the process of maturation the number of chromosomes is reduced by one half in both the egg and sperm cells, so that upon fertilization the typical number of chromosomes in the embryo is again brought to normal. The reader should keep

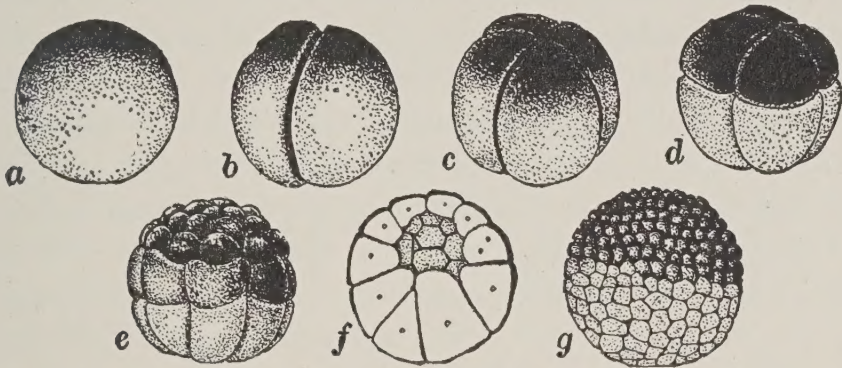


FIG. 67.—Early stages of the development of the frog. In the frog's egg there is a considerable amount of food matter, or *yolk*, in addition to the protoplasm. This yolk material is heavier than the protoplasm, and remains at the bottom of the mass. So long as the cell divisions are in a vertical plane, *b*, *c*, all the cells formed may be alike; but when walls are formed in a horizontal plane, *d*, the upper cells will be smaller than the lower ones, for while all the cells may have the same amount of protoplasm, the lower ones will have larger quantities of yolk and will thus be larger, *e*, *f*, *g*. (From Gruenberg's *Biology and Human Life*, by permission of Ginn and Company, publishers.)

in mind that the chromosomes are the carriers of the inheritance fund, so that when the chromosomes are reduced in number in the egg and sperm cells, the inheritance fund of each cell is also reduced by one half, but it is restored to the full upon fertilization.

Very shortly after fertilization the egg attains a bilateral symmetry in structure. This symmetry is shown by the position of the pigments of the cell and it is related to the direction from which the spermatozoön entered; in the majority of the cases the first cleavage plane divides the egg into right and left halves. The cleavage or division of the frog's egg is total and unequal—that is, the entire egg divides into definite parts, daughter cells, but the cells resulting are of different sizes. In some forms of ani-

mals having less yolk in the egg, the divisions are often almost equal in size; and in still other forms where the yolk is much more abundant than in the frog's egg, the division includes only the protoplasmic portion at the animal pole, the yolk remaining uncleaved.

In the first cleavage a furrow makes its appearance on the surface at the animal pole, and this soon extends as a narrow groove around the vegetative pole. If the water is not too cold, the first cleavage is usually accomplished in less than three hours. The fact that this first division takes place so soon after fertilization is the reason why it is so difficult to get frogs' eggs in the one-celled stage. In about an hour's time the second cleavage occurs at right angles to the first, resulting in four cells of equal size. Since the second cleavage takes place so soon after the first, it is also difficult to collect frogs' eggs with only two cells. The third cleavage is typically at right angles to the first two, and for the first time the egg is then divided into cells of unequal size. Those at the vegetative pole are considerably smaller and richer in yolk than those at the animal pole, which are protoplasmic.

Typically the fourth cleavages are meridional, thus forming eight smaller cells in the upper area and eight larger ones in the vegetal region. The fifth soon follows, resulting in thirty-two cells which are nearly always arranged in four horizontal rows. From now on the cleavages of the cells at the animal pole are much more rapid than those at the vegetal pole, and in neither division are all of the cleavages visible on the surface. At about this stage also a cavity begins to form among the cells, somewhat closer to the animal pole. This cavity is called the *segmentation cavity* or *blastocœle*. By this time there are about sixty-four or one hundred twenty-eight cells. Approximately one fourth of the cells are in the interior, lining the blastocœle, and the other three fourths are external, so that at this stage there may be two or more thicknesses of cells somewhat modified but not yet of two distinct kinds or layers such as we shall find developing very shortly. When there is just one layer of cells with the blastocœle in the center, we have a typical blastula. At this stage also the

interior cells divide more rapidly than those of the exterior, and some of the latter may migrate to the inner surface.

Up to this time the egg has remained about spherical and has changed little in size, although perhaps several hundred cells now occupy the area formerly filled by the original single fertilized egg. Very shortly the animal cells tend to push downward and the internal yolk cells to rise, so that the bottom of the blasto-

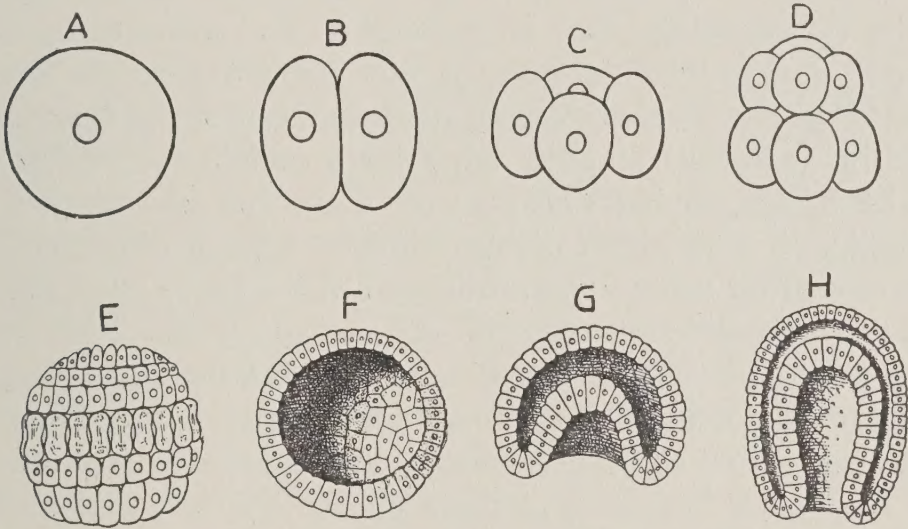


FIG. 68.—Stages common to all Metazoa. A, egg; B, C, D, cleavage stages; E and F, blastula, in F, which is somewhat older than E, one half has been removed; G, beginning of gastrular invagination; H, complete gastrula; G and H sectioned as in F. (From Lull, after models of *Amphioxus* by Hatschek.)

coele is nearly flat, then convexly arched, and at the same time it widens out so that the cavity is somewhat crescentic in appearance.

At this stage the *blastula* is completed and the gastrulation process begins. The blastula consists of a single primary germ layer with the cells arranged in the form of an epithelium.

The blastula of the frog, as has been noted, is bilaterally symmetrical, has been differentiated into anterior and posterior ends, has large yolk-filled cells which are consequently less numerous than the small cells near the animal pole, is nearly spherical and has increased in size but little, is heavily pigmented over the ani-

mal half, and has a prominent *blastocœle* located mostly if not entirely above the equator.

The next stage, the *gastrula*, is quite different from the blastula when complete, but naturally the exact boundary line is hard if not impossible to locate, since the processes of development are continuous and one grows gradually into the other.

In the early gastrula stage of the frog's egg, we find the cells forming the lower margin of the germ ring (posterodorsal region) to be invaginating—that is, turning in and growing up and around close to the outer layer of cells. We now have the beginning of the two-layered embryo, the outer layer of which is called *ectoderm* (epiblast) and the inner layer *endoderm* (hypoblast).

The accompanying drawings represent the gastrulation in *Synapta*, an echinoderm with a primitive type of development. The reason for using *Synapta* instead of the frog's egg to illustrate the complete formation of the gastrula is that it has very little yolk and the exact process of invagination can be more easily understood than if the frog's egg were used. (See Fig. 69.) It is evident that as the invagination of the endoderm continues, the blastocœle is more and more obliterated, but that at the same time a new cavity is forming called the *enteron* or *primitive gut cavity*—a cavity that will give rise to the chief cavities of the later embryo, including the digestive cavity. In the frog's egg the cavity, although not apparent, is present and will play a prominent part in the development of the embryo when the yoke cell mass is used up.

A typical frog gastrula has several prominent characteristics, probably the most important of which are its two distinct layers, the outer called *ectoderm* and the inner *endoderm*, thus differing greatly from the blastula, which has only one layer. A two-layered embryo is spoken of as *diploblastic*. It is somewhat elongated, often somewhat flattened, and very distinctly bilaterally symmetrical. In *Synapta*, bilateral symmetry is late in developing.

This actual two-layered condition normally lasts but a short while, when other important processes begin to take place.

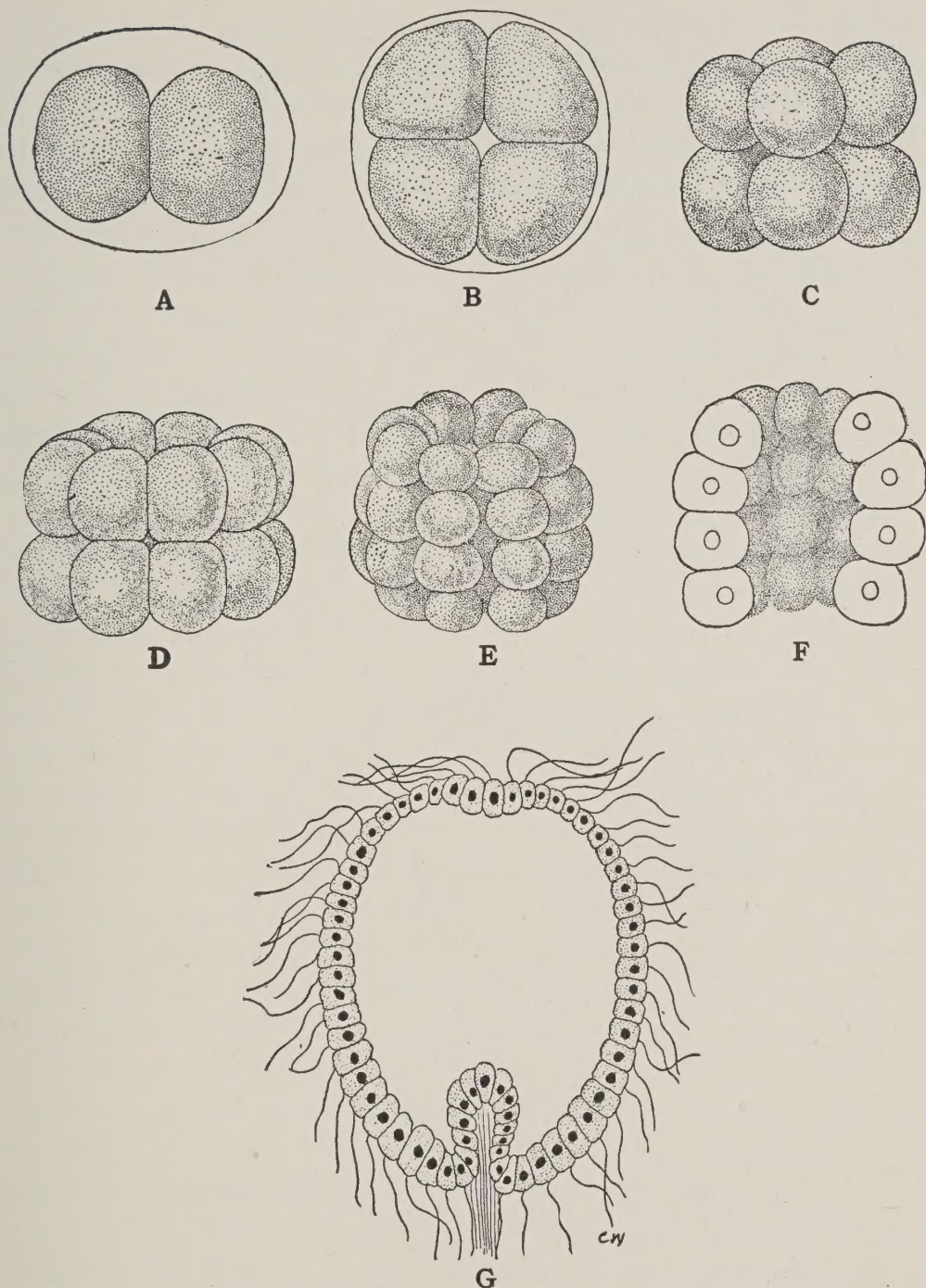


FIG. 69.—Cleavage of *Synapta digitata*. A, side view of two-cell stage; B, four-cell stage; C, eight-cell stage; D, sixteen-cell stage; E, thirty-two-cell stage; F, thirty-two-cell stage in section; G, gastrula stage. (From Korschett and Heider, after Selerka.)

Just as it is characteristic of the lowest form of life to be made up of one cell or a group of cells more or less loosely arranged into one layer, and for a group of animals a little higher to have two layers, so it is characteristic of all the other phyla (branches) of animal life to have three layers, the ectoderm, endoderm, and

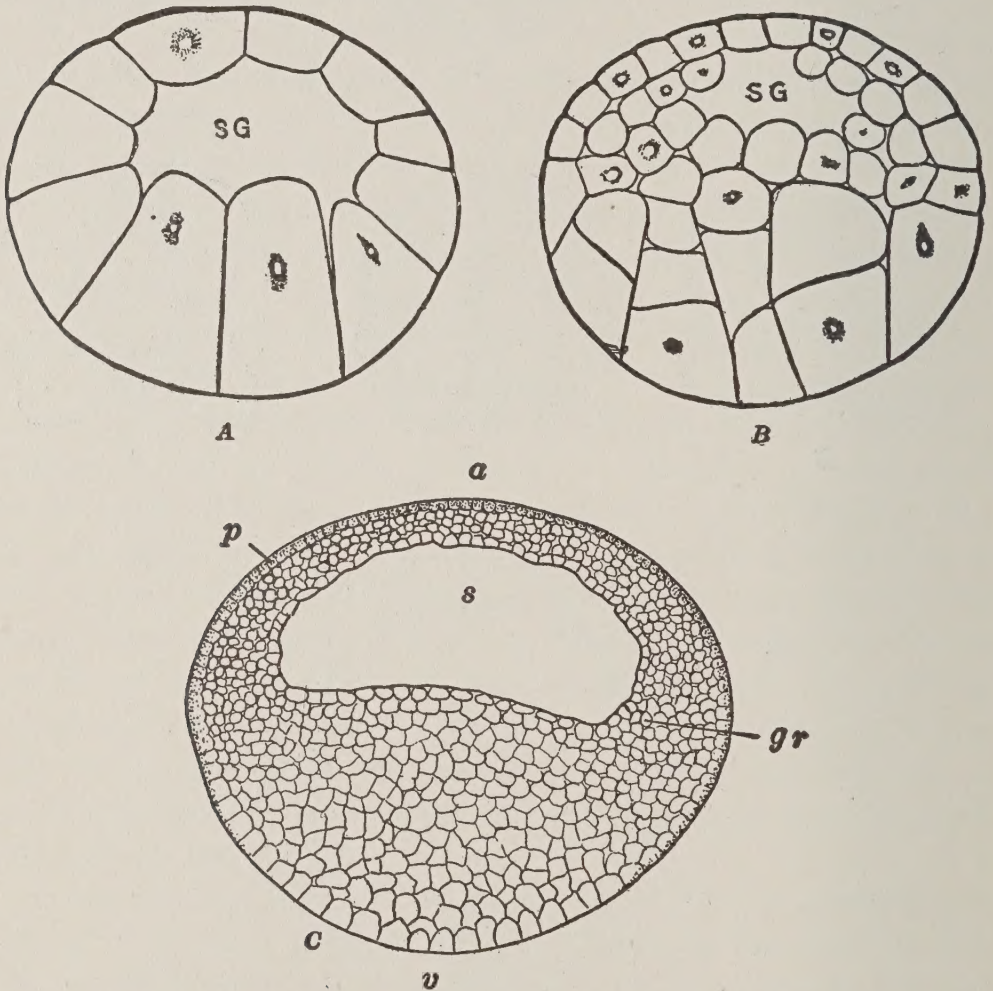


FIG. 70.—Sections through the blastula of the frog. A, B, from Morgan, *Development of the Frog's Egg*. C. After O. Schultze. A. Early blastula showing wall of segmentation cavity only one cell in thickness. B. Later stage showing multiplication of cells in wall of segmentation cavity. C. Late blastula showing the thinning of the roof of the segmentation cavity and the beginning of the germ ring; a, animal pole; gr, germ ring; p, pigment; s, segmentation cavity or blastocœle; SG, same as s; v, vegetal pole. (From Kellicott, *Outlines of Chordate Development*, by permission of the publishers, Henry Holt and Company.)

mesoderm. In fact, it is impossible, as will be shown later in this chapter, for a higher form of life to develop without the appearance of the mesoderm in the embryo.

The exact method of derivation of the mesoderm varies, but the method used by the frog is usually considered fairly typical of vertebrates. In the gastrula the rudiments of the mesodermal layer are found in a group of cells lying in the dorso-lateral region of the endodermal archenteric wall. These cells rapidly increase in number, and form a definite layer between the ectoderm and the endoderm. We thus have a three-layered triploblastic embryo, an embryo that is capable of developing into a complex animal having all of the complex systems found in vertebrates.

Because of the painstaking work of many embryologists, we now know the exact derivation of all the fundamental parts, and even of the lesser parts, of the vertebrate body. This is even true of the human embryo, although the specimens to be studied are not so abundant since they can usually be secured only under conditions of premature birth, or occasionally of accident. Opportunities to study the very earliest stages of human embryology have been rare, but in so far as the processes are known, they are so similar to those of the higher mammals that one may safely outline the very definite steps which take place in the early history of the human embryo.

It is important to know that the ectoderm of the embryo gives rise to the skin, the brain, the central nerve cord, the eyes, most of the external and internal organs of hearing, the nails, the hair, and several minor parts of the body. The endoderm gives rise to the epithelium of the digestive tract with its glandular derivatives, the pharynx, and the respiratory tract. The mesoderm gives rise to most of the muscles, the heart, the blood vessels, the blood, the excretory and generative organs, and the connective and supporting tissues which include the bones.

More primitive forms of animal life, such as of the hydra or of the coral, are only diploblastic (two-layered animals) and thus essentially gastrula. Knowing this simple fact and the fact that the mesoderm arises only after the ectoderm and endoderm have

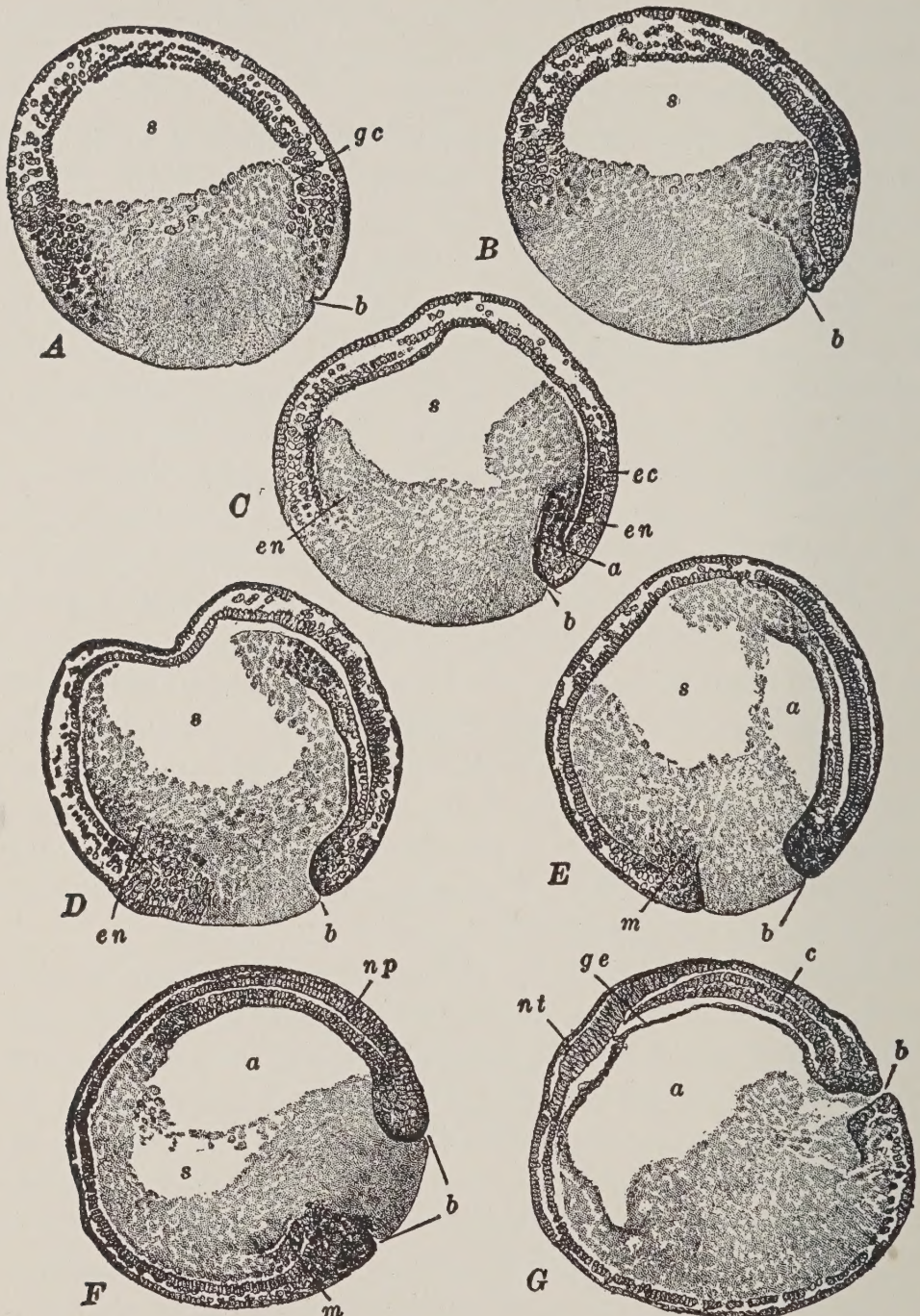


FIG. 71.—Median sagittal sections through a series of gastrulae of the frog (*R. temporaria*). After Brachet. The figures illustrate the change in position of the whole gastrula, as well as phenomena of gastrulation proper. A, Commencement of gastrulation; earliest appearance of the dorsal lip of the blastopore. Internally the gastrular cleavage is indicated.

been formed, one can understand why the hydra and the corals do not have a heart or a circulatory system. They do not develop the layer in the embryo out of which these parts are made. One can quite accurately define a complex form of animal life by saying that it is one that develops the mesoderm in its embryonic or larval stages.

A hydra or a coral is more complex than a sponge, for in the latter the cells, although loosely arranged in layers, do not present the definite organization into outer epithelial covering and inner digestive tissue sheets that are found in the former. Since the digestive system is dependent upon the development of the endoderm, one would expect the hydra and the coral, in which this layer is first clearly organized as such, to have at least a primitive digestive system, and upon examination we find that this is true. Sponges do not have even a primitive digestive system which serves all the cells in a large sponge colony and each sponge cell is practically an independent unit in the ingestion and digestion of food.

The even more primitive protozoan does not have a heart, circulatory system, or digestive system, since it does not have even one layer of cells, so that whatever activities are carried on by it must necessarily be very generalized. As individual cells some protozoa are highly specialized, but as animals they lack entirely the structural basis for the development of the organs common to the higher forms. The outer wall of the protozoan is not epidermic since it does not possess the ectoderm layer out

B, Invagination more pronounced; beginning of epiboly; *C*, Invagination, epiboly and involution in process. The gastrular cleavage is now indicated on the side opposite the blastopore. Rotation on the gastrula. *D*, Just before the ventral lip of the blastopore reaches the median line. The indentation of the wall of the segmentation cavity is an artifact. *E*, Blastopore circular and filled with yolk plug. Gastrula beginning to rotate back to its original position. Peristomial mesoderm differentiating. *F*, Segmentation cavity nearly obliterated. Neural plate established. *G*, gastrulation completed. *a*, Archenteron; *b*, blastopore; *c*, rudiment of notochord; *ec*, ectoderm; *en*, endoderm; *gc*, gastrular cleavage; *ge*, gut endoderm; *m*, peristomial mesoderm; *np*, neural plate; *nt*, transverse neural ridge; *s*, segmentation cavity or blastocœle. (From Kellicott.)

of which epidermis is derived. The digestion carried on cannot be in a stomach since it has no endoderm, the layer out of which the inner part of the stomach is made, and as previously stated, it cannot possess a heart because of the absence of the mesoderm layer. In short, the embryologist can readily tell by the early development of the embryo whether the adult will be a simple or complex animal.

The organ that is the most significant to mankind is the brain; hence its derivation will be given in considerable detail.

In most vertebrates shortly after the formation of the endoderm, the ectoderm begins to invaginate or "pinch in" along the median dorsal part of the embryo. The depression thus made is called the *neural plate*. This plate becomes deeper and continues backward so that almost throughout the entire length of the embryo a groove is formed. The ectoderm bordering on this neural plate becomes slightly raised in ridges and these are known as *neural folds* or *neural ridges*. The neural folds soon approach each other medially and cover over the neural plate, beginning at the posterior end. In the region of the anterior end a larger amount of ectoderm is usually invaginated, and we then have a larger mass which later enlarges to form the fore-brain.

In the higher vertebrates the nerve cord is covered by lateral arched processes of bone from the vertebræ. Thus in effect a hollow bony tube, the vertebral column, is created throughout the length of the embryo as a protection for the nerve cord.

If there were time, we could show in detail how the eyes develop as outpockets of the brain; how the ear develops in a somewhat similar way; but the reader will have to refer to a standard embryology for these facts, since it would take many pages to give them. It should be emphasized at this point, however, that the complete development of almost every organ and part of the body is known from its beginning in a large number of animals. No longer do we have to speculate or guess how the various parts of the body come to their complex condition or out of what materials they are made.

One of the four basic concepts upon which modern biology rests is the idea of the continuity of life—that is, that there has been an unbroken germ stream from the beginning. Each form of life inherits some of its traits from the very first generation. It is true that the traits inherited may be greatly modified—so much so, in fact, that it is often difficult to make out any connection with the past or to interpret the past in the light of the present.

The fact that this generation has received its inheritance from the preceding generation, and the preceding generation in turn from the one just preceding it, and so on indefinitely, led to the promulgation of the recapitulation theory. Stated briefly, this implies that the individual lives over again, either in the embryonic or post-embryonic stages, the life of the race. An expression once widely used was that “ontogeny recapitulates phylogeny.” By *ontogeny* we mean the life history of the individual’s development, and by *phylogeny* the life history of the race’s development.

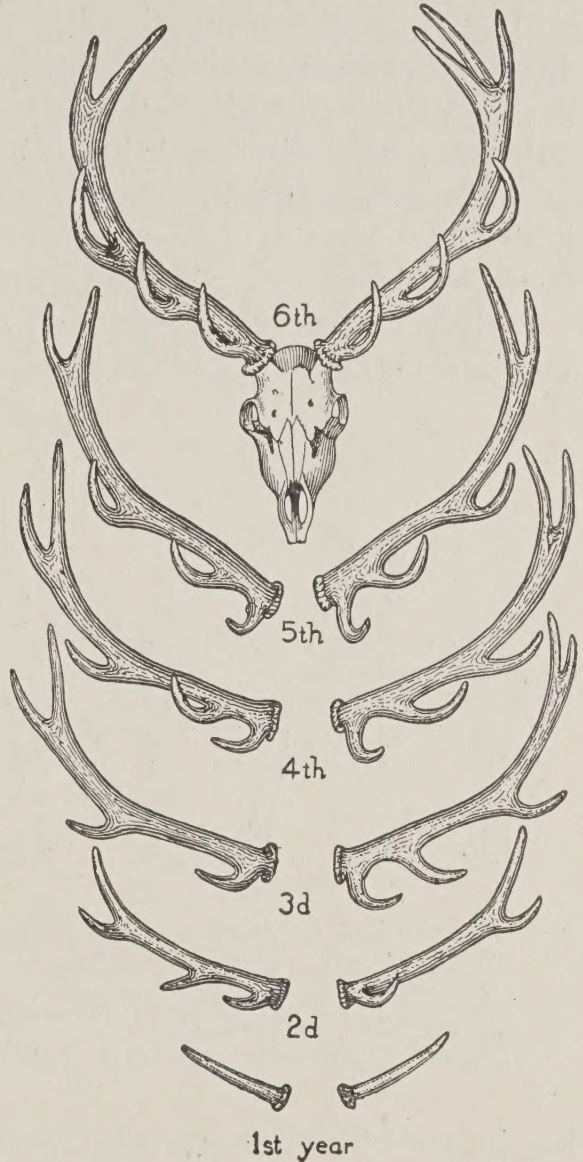


FIG. 72.—Antlers of stag, showing ontogenetic increase in complexity. Series in the British Museum of Natural History. (From Lull, after Romanes' *Darwin and After Darwin*. Copyright, Open Court Publishing Co.)

Perhaps no theory in recent years, except the theory of evolution, was more widely heralded and acclaimed than this theory, and in a very short time the theory was accepted by many as a fact, but without sufficient investigation and research to verify it. As is the case with many popular theories, there are some important and well-grounded facts back of this theory, and there are some gross exaggerations and complete errors connected with it also. It is the aim of the next few paragraphs to point out the facts and the errors of this theory.

It should be stated with the greatest emphasis that there are thousands upon thousands of species that are not in the line of

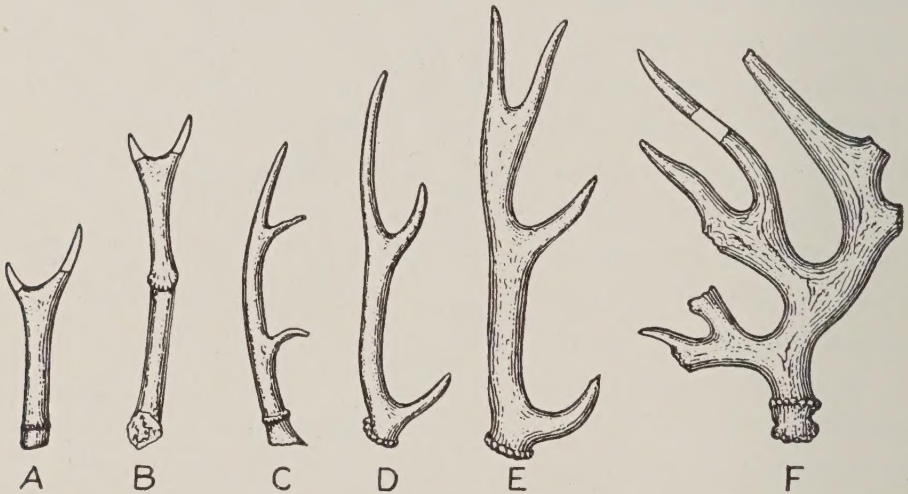


FIG. 73.—Antlers of deer, phylogenetic series. A, B, *Cervus dicrocerus*, Middle Miocene; C, *C. Matheronis*, Upper Miocene; D, *C. pardinensis*, Upper Miocene and Pliocene; E, *C. issiodornensis*, Pliocene; F, *C. sedgwickii*, Pleistocene. (From Lull, after Romanes' *Darwin and After Darwin*. Copyright, Open Court Publishing Co.)

human ancestry or of any other vertebrate, and therefore there is no possible chance of their recapitulation in vertebrates. It is not even certain that all forms of life go back to one common species as an ancestor.

That the human embryo recapitulates all the vertebrates, including the fish, the amphibia, the reptiles, the birds, and the mammals is manifestly absurd. There are doubtless certain traits of fishes, amphibians, reptiles, and the more primitive

mammals that are present in the embryo of the human being, but there are no bird traits of any kind. Not with the greatest stretch of imagination can one think of a bird trait recapitulated in any mammal. The birds represent an entirely separate branch of life out of which no other forms have evolved. It is probable, too, that they are also far too specialized to give rise to other orders, families, or species. The mammals also represent an en-

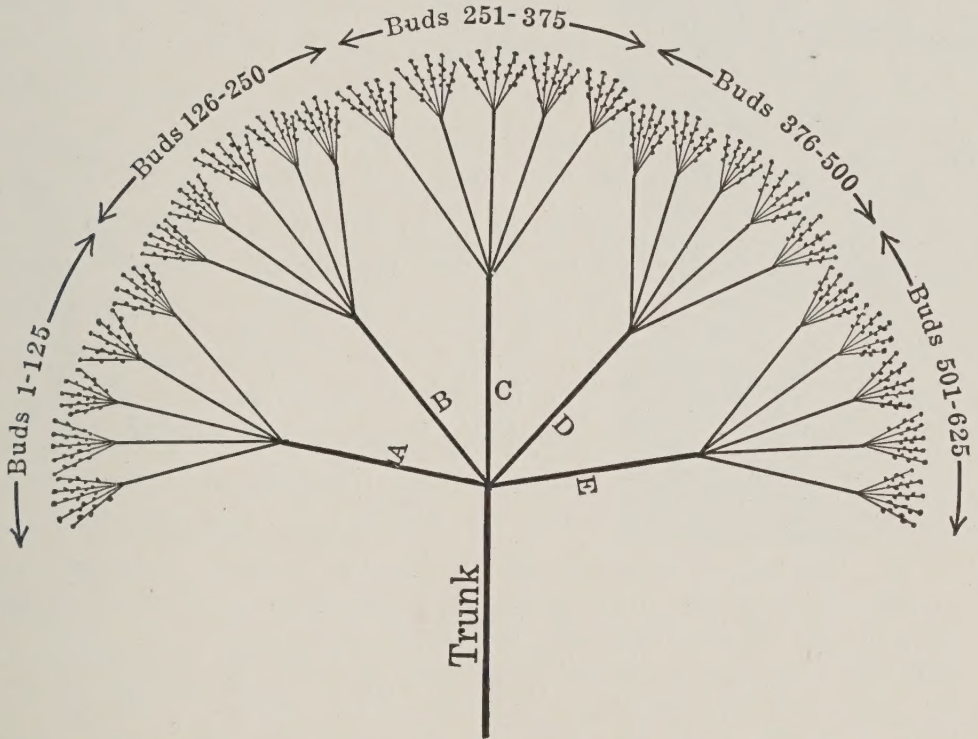


FIG. 74.—Diagrammatic drawing illustrating the possibility of one species to recapitulate another species. Each bud on each branchlet represents a species.

tirely distinct and separate branch, and from this branch no other large division of life has evolved. It is true that certain reptilian characters would be possible in the embryos of both birds and mammals, since it is a well-established fact that the reptiles have given rise to both the birds and the mammals.

If we compare life to a tree, as is so often done, and let the buds at the top of the smaller branches represent the many species that exist, then we have a fairly accurate picture of the relation-

ship that might exist between two buds on separate branches. This would also represent the possibility of the recapitulation of one in the other. We shall let our tree have five main limbs coming out of the trunk, with these in turn having five smaller

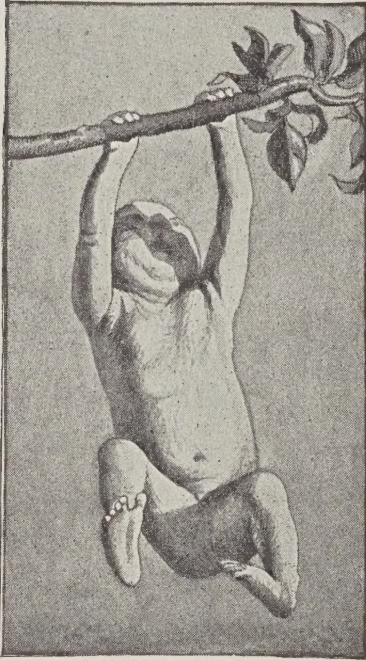


FIG. 75.—An infant three months old supporting its own weight for over two minutes; the attitude of the lower limbs is strongly simian. (From *Evolution and Animal Life* by Jordan and Kellogg, after Romanes. By permission of the publishers, D. Appleton and Company, New York.)

branches each, and these smaller branches each having five still smaller branches, with five buds each (Fig. 74). We shall call the five main branches A, B, C, D, E, and each of the buds 1, 2, 3, to a total of 625 for all branches—the first one hundred and twenty-five on branch A; the second one hundred and twenty-five on branch B; the third one hundred and twenty-five on branch C; the fourth one hundred and twenty-five on branch D; and the last one hundred and twenty-five on branch E. It would seem obvious then that buds 126 to 250 would not recapitulate buds 1 to 125, since they are on distinctly separate branches; that buds 251 to 375 would not recapitulate buds 126 to 250; or that buds 376 to 500 would not recapitulate buds 501 to 625. The buds mentioned are not in direct line with any of the others and cannot possibly be descendants or ancestors of them.

Another common assumption is that the human being recapitulates the adult character of his ancestors—that is, that in his embryonic development he looks like the adults of the species in his ancestral line. This is decidedly erroneous because the adult forms are far too specialized in most species to be ancestral to any other kind of creature, just as certain well-known species are over-specialized, like the ex-

ceedingly long-billed humming-bird, which cannot be ancestral to the other humming-birds. Only generalized animals seem ever to have become the ancestors of higher forms. The human adult is a very specialized creature in regard to his nervous system, and therefore probably cannot give rise to other higher forms. The adult form also as expressed in most species both past and present is usually far too recent to be registered in the life of the embryo. The present adult stage, instead of being the oldest phase of life, as one might infer, is the youngest. The

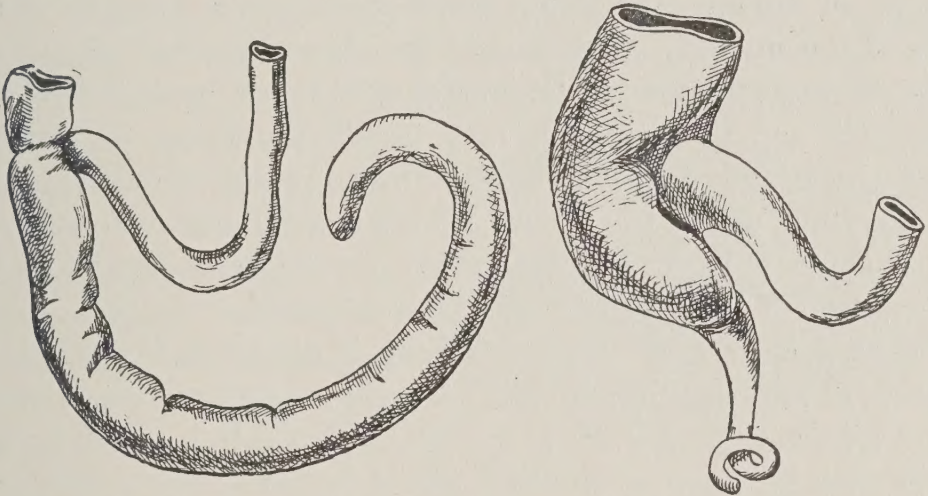


FIG. 76.—Vermiform appendix of kangaroo, at left, and human embryo, at right, after Wiedersheim. (From *Evolution and Animal Life*, by Jordan and Kellogg, by permission of the publishers, D. Appleton and Company, New York.)

child represents an older and at the same time a far more generalized condition than the adult.

Various estimates have been placed on the length of time that life has been on the earth, but all scientists who have studied the question agree that life has been on the earth at least one hundred million years. Indeed this number is more than doubled by most paleontologists. If we assume that ancestry goes back to the one-celled stage at least one hundred million years ago, as all evidence seems to show, it is clear that in the course of the nine months of foetal life about one hundred million years of time are recapitulated. This means that

on the average each month of the embryonic life recapitulates about eleven million years in the life of the race! Each day of the embryo's life on the average would correspond to about three hundred seventy thousand years and each hour to over fifteen thousand years. Under these conditions, anything approaching specific recapitulation is a *reductio ad absurdum* on its face.

It is obvious then that only exceedingly important and long-enduring traits would ever have a chance to be expressed embryonically. Periods of time that are long in the life of the nation or of all human civilization correspond to but minutes in the life of the embryo. According to the above estimate, all written history corresponds to about twenty minutes in the life of the embryo, and the entire history of Britain since the Romans left the island, to about six minutes. In all of our thinking about time, we are too prone to think in small units. If we could only think in larger units, many of our disputes concerning the formation of the species would be less heated.

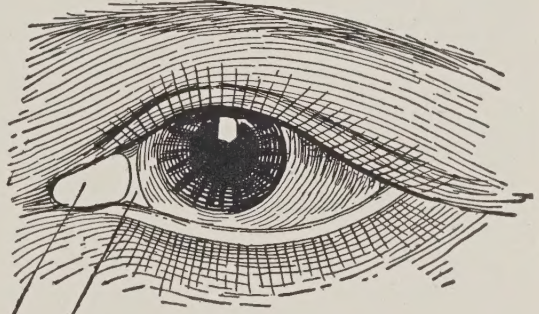
Occasionally a species or a family is discovered in which all traces of ancestral life are lost and nothing in the embryological development gives even a clue to the ancestral structure and relationship. Such a condition could be forced upon a species particularly if the habits of living have been greatly changed, as in some of the insects. If a species in its early history lived in the water and now lives only on land, even in the egg and larval stages, it is quite possible that structures adapted to water conditions might be mostly or entirely obliterated and new ones added in a forced adaptation to land conditions. We can take one stage in the life history of the housefly to illustrate the point in question. The remote ancestors of the present housefly lived in water, but upon emergence to a land habitat, the *pupa* stage has been added with its heavy and almost impervious covering. This heavy covering is necessary to the fly to-day to protect it during the transition from the larva to the adult, but it was wholly unnecessary to the ancestor of the fly and hence was not present. Here is something expressed before "birth" which was not even present in the ancestral fly.

The matter of vestigial structures has often been presented as an argument in favor of recapitulation, and it is well that we should examine the facts in the light of modern researches. First of all there can be but little doubt that there are, in the bodies of nearly all forms of animal life, many useless or nearly useless structures which were at one time decidedly useful and necessary to the life of the animals possessing them. Such structures are called vestigial organs.

The famous anatomist, Wiedersheim,¹ stated that the human body contains at least one hundred and eighty-one vestigial structures. That all of the structures which he enumerated are strictly vestigial might be questioned by some, but that they are not necessary to the life of the individual probably can be demonstrated easily in most cases. In fact, in numbers of cases it has been demonstrated that some structures are worse than useless; they are disease-producing in some instances and the causes of decidedly severe pain in others.

Perhaps the most outstanding example cited as a vestigial organ in the hu-

man being is the vermiform appendix, a small blind sac, now reduced to about an inch and a half in length by a quarter of an inch in diameter. Other outstanding examples of human vestigial organs are the hair on the arms, legs, and trunk, the wisdom teeth, the muscles of the ear, the muscles of the scalp, the pineal eye, the nictitating membrane of the eye, the gill arches in the neck, and the bones in the rudimentary tail.



Cl. Ps.

FIG. 77.—The human eye showing the nictitating membrane, or vestigial eyelid. *Ps.*, Plica Semilunaris; *Cl.*, Caruncula lachrymalis. (From *Evolution and Animal Life* by Jordan and Kellogg. By permission of the publishers, D. Appleton and Company, New York.)

¹ Wiedersheim, R. E. E., a German scholar who made outstanding contributions to our knowledge of human anatomy.

To some it might seem that the evidence thus far presented is insufficient or inconclusive to prove that there is such a thing as a vestigial organ. Such persons might claim that since no person now living was living when these vestigial organs were useful, we do not know them to be vestigial, and that they may have important functions to perform as do other parts of the body, if the functions could only be found. Such persons might also claim that the people living when these vestigial structures were useful to the life of the individual have left no written record or even a hint of these functions, and therefore

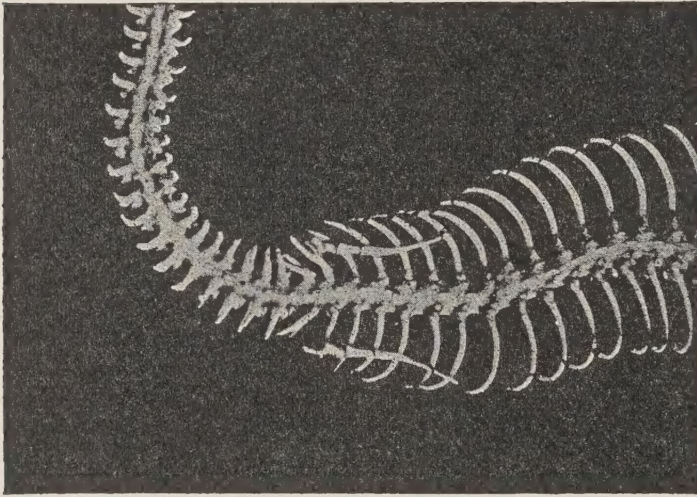


FIG. 78.—Part of the skeleton of a boa constrictor, showing the vestigial bones of the hind limbs. From a specimen in the United States Museum. (After Metcalf.)

it cannot be held that there are any organs which were formerly functional but are now useless.

There are several fallacies in such arguments. The first lies in the assumption that structures once very useful can become entirely vestigial so soon—that is, in

the course of the few thousand years that form the total length of written human history. No biologist holds that transition from useful organs to completely useless ones ordinarily takes place in so short a time, but rather that several score times as many years are probably necessary. It certainly has been a long time since the human being needed the tail bones, and yet the remnants still persist.

One of the best established facts of biology is that few of the several hundred thousands of species of life on earth represent absolutely perfect adaptation to their environment with no

vestiges of once useful parts—that is, there are few perfect physical specimens. Nor does it seem necessary to assume physical perfection in the human body when one recalls that no one attempts to hold that mentally and morally the human being is a perfect specimen.

The majority of the human being's vestigial structures started to become useless long before man wrote a word, and many while the species was in a quite sub-human state. Two cases will be enough to prove this statement. The tail bones of the human being, which now are usually four in number, are very much reduced and doubtless came almost if not entirely to their present condition, long before the advent of man as such. We find these reduced tail bones in the anthropoid apes almost to the degree found in man. Now it is well known that both the anthropoids and man have prominent tails in the embryonic stage and that these continue to reduce in size until only vestiges remain when the adult stage is reached.

The nictitating membrane is to be found only as a little pimple-like structure about the size of a large pinhead in the inner angle of the eyes close to the nose. It is slightly more prominent in other mammals. This membrane is useful to-day in many of the lower forms in cleaning the eye, and can be easily seen if a chicken is watched for a few minutes or if one observes a frog, toad, or alligator. The nictitating membrane is no longer needed in the mammals since its place has been taken by the eyelid, and the functions of the former are now performed by the latter. For this reason it has been greatly reduced in size and theoretically it continues to become smaller and smaller as the centuries pass.

On the front foot of the dog one toe is greatly reduced and functionless. It does not even touch the ground—it dangles aimlessly in the air, and sometimes is a positive disadvantage when snow and ice accumulate around it. The horse has two splint bones on each foot, the remnants of the once useful toes in Eocene, Miocene, and Pliocene times. Most ducks have a very small hind toe thoroughly useless, but we know that in some of

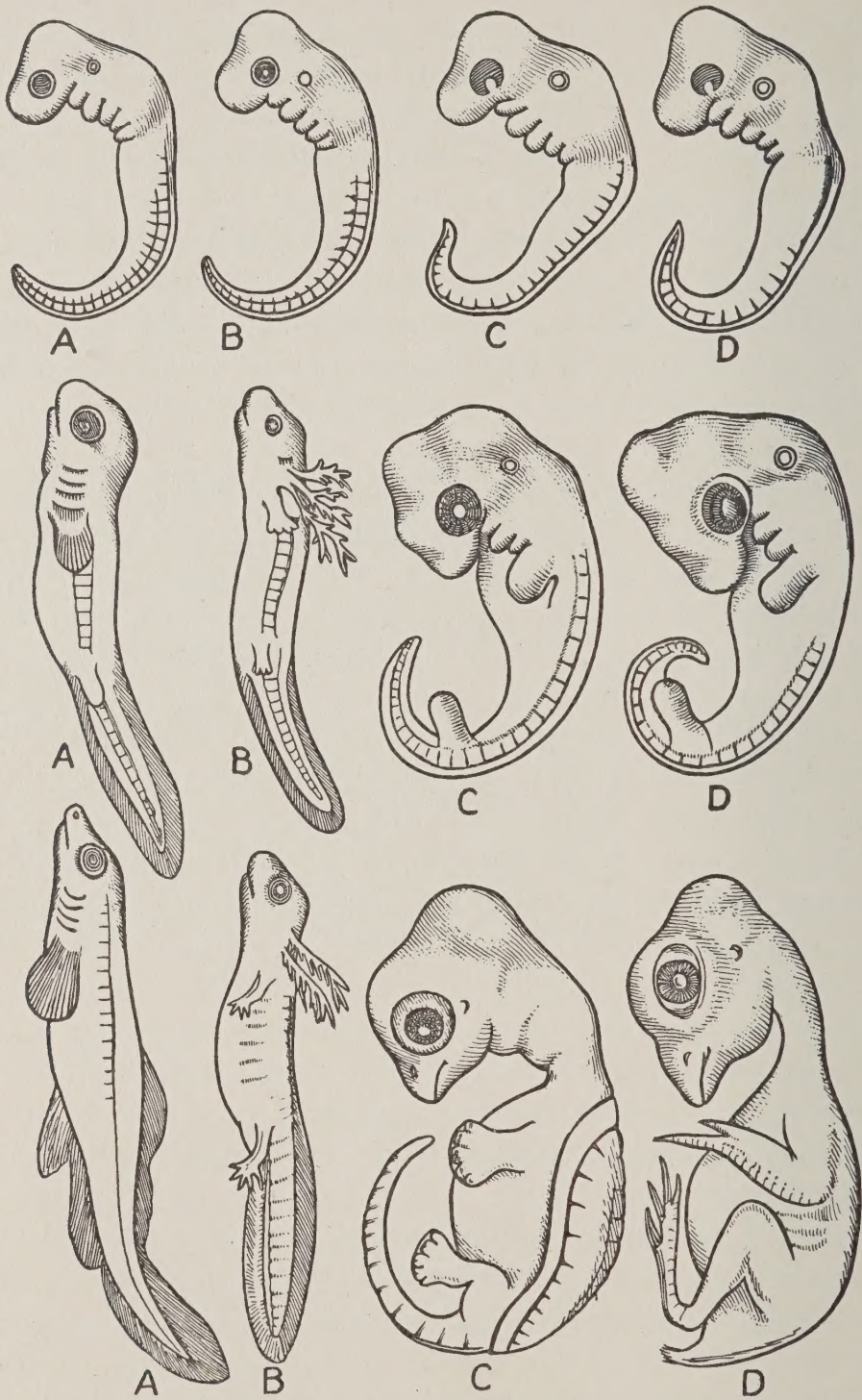


FIG. 79.—Series of vertebrate embryos at three comparable and progressive stages of development. A, fish; B, salamander; C, tortoise; D, chick (continued).

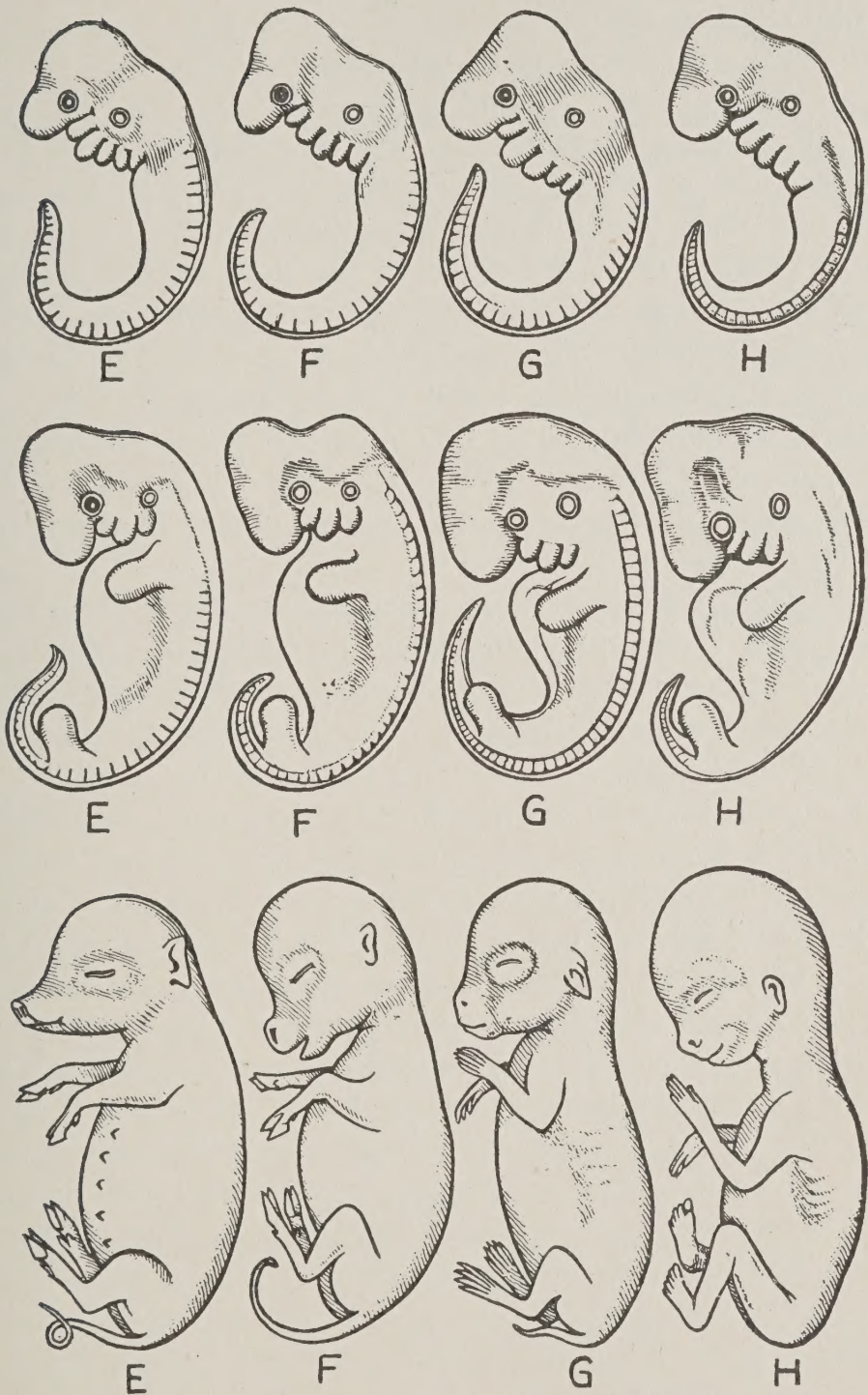


FIG. 80.—Series of vertebrate embryos (cont'd). E, hog; F, calf; G, rabbit; H, human. (From Lull, from Romanes' *Darwin and After Darwin*. Copyright, Open Court Publishing Co.)

its bird relatives the hind toe is a very useful part. In the golden plover the hind toe seems at first glance entirely lacking, but when the inside of the foot is examined, we find remnants present. In the apteryx or kiwi, a bird of Australia called the wingless bird, there are very small totally useless wing bones under the skin. The boa constrictor also has small vestiges of legs under the skin, embedded in the flesh, recalling a time when the legs were useful organs. Some of the large whales weighing fifty tons and more also have embedded in the flesh tiny remains of hind-leg bones scarcely larger than the arm bones of man. Hundreds upon hundreds of other vestigial structures, more or less prominent, have been observed in other animals, and descriptions of these can be found widely distributed in zoölogical literature.

The plants also exhibit many vestigial structures and shapes. Eucalyptus leaves on young trees have the same shape and mode of attachment that was characteristic in Mesozoic times of all the leaves of full-grown trees. The quaking aspen tree exhibits nearly always in its early growth the type of leaf that characterized the full-sized tree in ages past. It should be added that the vestigial factor does not lie in the fact that the leaves of the eucalyptus and quaking aspen trees are small and useless, or nearly so, but that they express the ancestral leaf shapes only in the younger branches of the tree.

The evidence regarding vestigial structures may be summed up by saying that such structures exist by the thousands; and that if a structure played a prominent part over a long period of time, this structure is likely to be found embryologically or post-embryologically, either in vestigial or in a useful form different from its original utility in the individual. The outstanding exception to this rule is found in the case of animals whose life history has been so modified that even in the embryonic or larval condition these vestigial structures have had to be entirely repressed to insure survival and new structures allowed to take their place, as in the case of the housefly discussed earlier in this chapter.

The theory of mental recapitulation was a natural inference from the facts of structural recapitulation. In the development of the child's mind definite "culture epochs" were supposed to correspond to the stages of civilization that the race has passed through. Many mental traits and tendencies were explained on the ground that they were "vestigial organs of the mind," persisting long after their useful functions had been outlived. Among the variations of this theory the following is typical: Every normal person, in his development from birth to adulthood, was said to pass through certain definite periods, called the *wonder*, the *wander*, the *heroic*, and the *romantic* stages. Exceptional individuals were said to pass through the *reflective* stage also, and finally a few into the *philosophic* stage. These last two stages, however, were believed to be the result not of recapitulation but of individual endeavor and ambition.

The reasons given for the first four stages in the life of the child are about as follows: the wonder stage of the child, lasting from birth until about seven years of age, was said to be due to the wonderings of the human race for tens of thousands of years as it was groping from the darkness of the animal mind into the light of knowledge and reason. Because the process was so long and fundamental, these wonderings of the primitive man were ingrained in the mind of the race, and consequently all children are filled with wonder and thrilled with tales of imagination like *Grimm's Fairy Tales* and *Æsop's Fables*.

Likewise for thousands of years humankind was migratory, moving from place to place as the food supply of one locality after another became exhausted. This impulse to wander, it was assumed, became ingrained in the mind of the race, with the re-



FIG. 81.—Head of a five-months human embryo showing embryonic hair covering. (From *Evolution and Animal Life* by Jordan and Kellogg, after Eckes. By permission of the publishers, D. Appleton and Company, New York.)

sult that every normal child, even if he does not run away from home, will at least enjoy tales of adventure and travel which permit a vicarious satisfaction, so to speak, of this impulse.

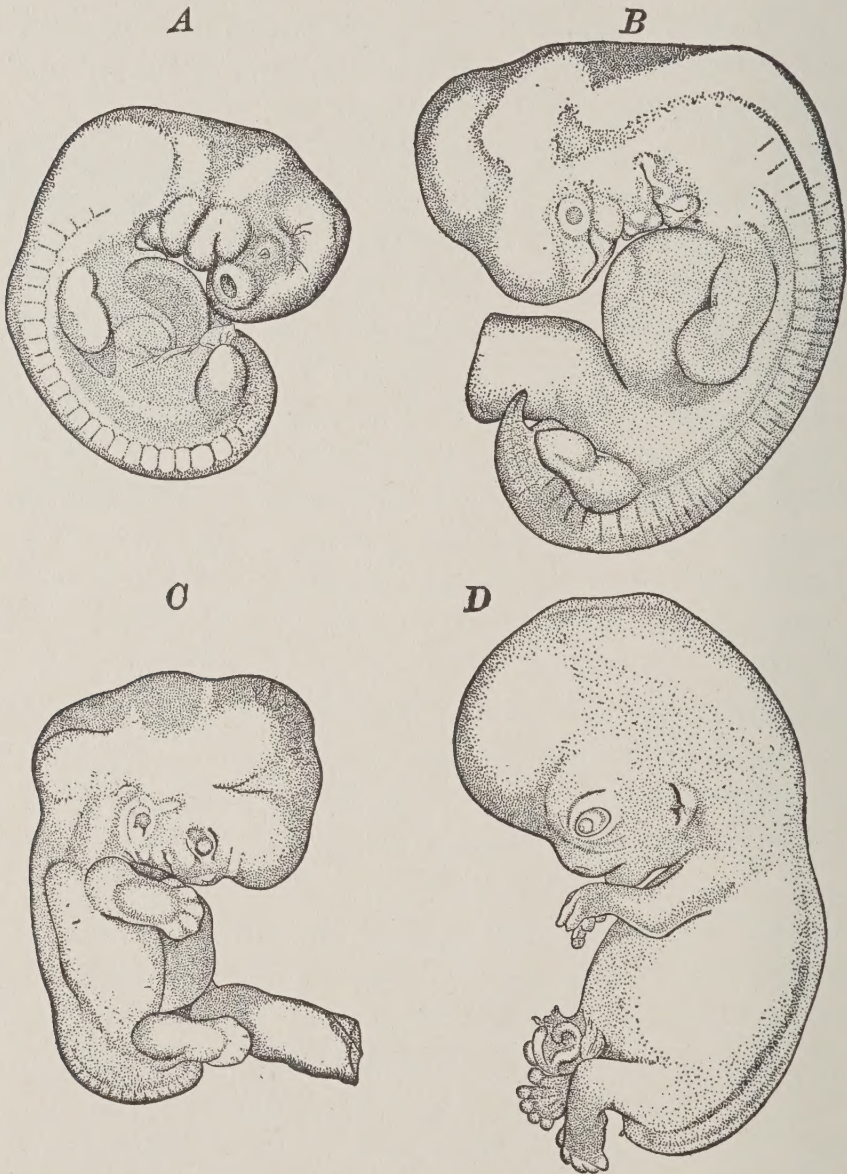


FIG. 82.—A, human embryo of forty-two somites; age about twenty-one days. B, embryo of about four weeks. C, still older embryo showing the beginnings of the formation of the digits. D, embryo of about two months. C and D are drawn on a smaller scale than A and B. (From Conklin, *Heredity and Environment*, after Keibel by permission of the publishers, The Princeton University Press.)

In a similar way, the heroic stage was said to be repeated in the experience of children. The race in its wanderings for thousands of years came into contact with other races on similar journeys; disputes arose, and fighting was the result. After thousands of years of fighting, the heroic or fighting spirit became ingrained, and consequently every child was supposed to be possessed during a certain period of development by the desire for battle.

The romantic stage, in its turn, was interpreted as the result of the practice on the part of the warriors of the tribes, of carrying off the beautiful daughters of their captured foes, and this habit oft repeated got into the germ plasm to such an extent that every boy and girl goes through the romantic or love stage.

The "culture-epoch" theory, as an explanation of certain mental traits and urges that are found in mankind, especially during childhood and youth, seems plausible on the surface, but it is quite inconsistent with biological principles. It assumes the "inheritance of acquired characteristics" and there is no satisfactory evidence that the acquired characters or the acquired knowledge of the adult can be transmitted to the child as such. (See Chap. XXIV.)

It is thus evident that not much is left of the culture-epoch theory upon which to base any sound educational principle. In fact the whole theory would be worse than useless, except for the fact that it has served to reëmphasize something that we already know—namely, that people are very much alike, particularly children, and that they do pass through several rather marked stages in mental development. The theory has possibly not been altogether bad in its effects. Although biologically indefensible it probably encouraged a thoroughly defensible policy of dealing with boys and girls, for there is little doubt that all normal children will evince certain dominant tendencies at about certain ages and then will leave these primitive stages behind. There is undoubted truth here, but it is not to be explained by the recapitulation of culture-epochs. In so far as is known, conscious experience can leave no record in the germ cell. The

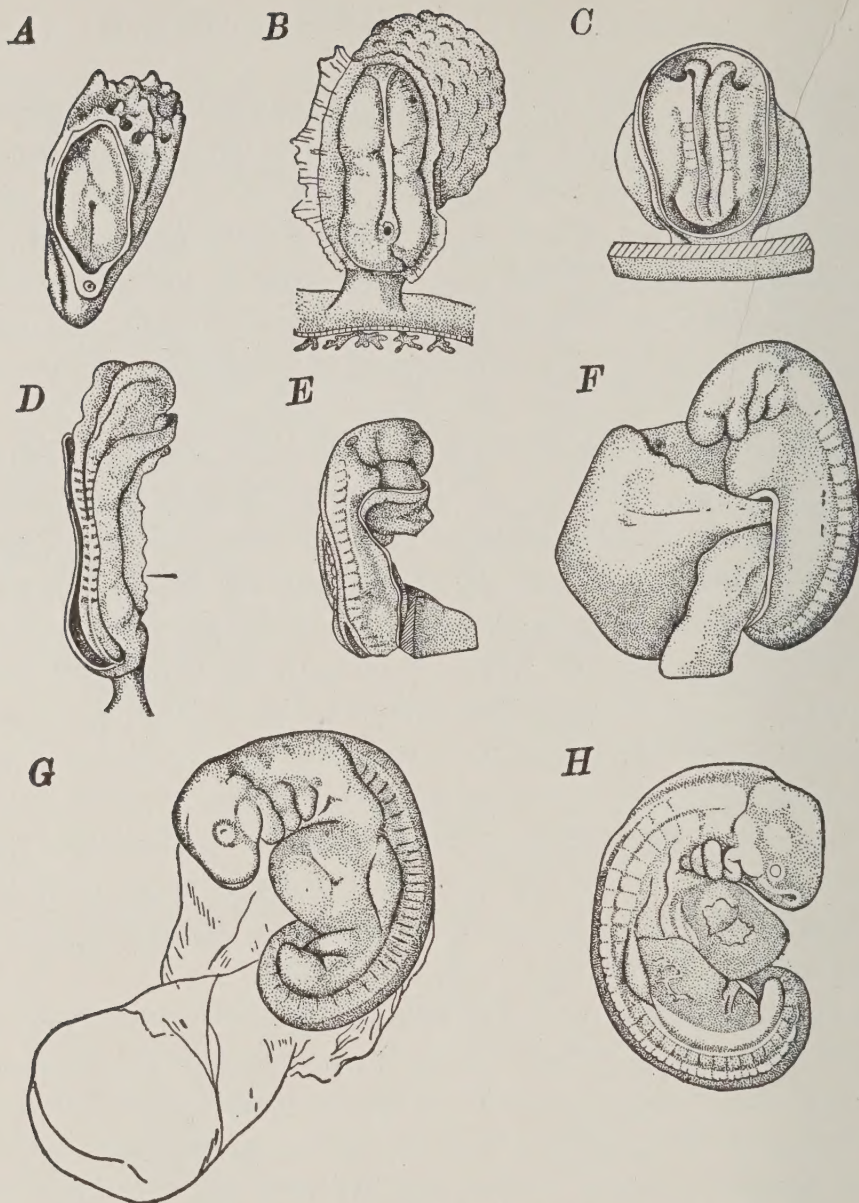


FIG. 83.—A–H, successive stages in the early development of the human embryo. A, blastodermic vesicle showing primitive axis in embryonic area; age unknown. B, blastodermic vesicle attached to uterine wall at the posterior pole, showing meural groove; age unknown. C, later stage in which the meural folds are closing and five pairs of somites have appeared; age, ten to fourteen days. D, stage of fourteen somites showing enlargements of the meural folds at the anterior end which will form the brain; age, fourteen to sixteen days. E and F, later stages, the latter with twenty-three somites and three visceral clefts. The ear shows a depression at the dorsal angle of the second cleft. G, embryo of thirty-five somites showing eye, branchial arches and limb buds. H, embryo of thirty-six somites, showing the nasal pit, eye, branchial arches and clefts, limb buds and heart. (From Conklin, after Keibel.)

results of experience are preserved only through objective records—implements, utensils, pictures, writings. And so far as thoughts and feelings are concerned, written or printed records alone are trustworthy—and not all of these.

Another idea related to the topic of embryology is that of *prenatal influence*. The notion is that a child's mental life and achievements can be influenced by what the mother thinks and wishes before his birth.

In so far as is known, there is no way in which the brain activity of the mother could directly influence the brain of the foetus before the birth of the child. It is conceivable, of course, that the mental state of the mother may have either a toxic or a depressing effect upon her own general health and thus indirectly exert an influence upon the health of the offspring. But a direct, specific effect upon the child's specific mental functions is unthinkable in the light of our present knowledge. About the only good thing that can be said for the theory is that some parents may have wished so ardently before his birth for a son to be a good doctor that they continued to wish for the same thing after his birth, wishing it strongly enough to give this son a chance to attend elementary school, high school, college, and finally a good medical school.

QUESTIONS

1. Are all animals either born or hatched? If not, do such animals recapitulate their past?

2. Can you suggest a way by which an individual could avoid recapitulating the dominant traits of his ancestors?

3. Do you think that traits or characters now found only in the embryonic stage of life were ever expressed as adult traits or characters in that species?

4. Why is it almost impossible to tell anything about the ancestry of modern protozoa by studying them immediately after cell division or conjugation has taken place?

5. In what way are vestigial structures of a species somewhat like the embryonic structures found in that species?

6. Why did not the highly specialized lower animals become the ancestors of the more highly specialized higher animals?

7. How has the study of embryology, recapitulation, and vestigial structures modified your point of view concerning the child?

8. How has it helped or hindered your conception of some teaching or disciplinary problems?

9. Are any of the facts referred to in this chapter suitable for instructional purposes in the elementary school? In the junior high school? In the senior high school? If so, where and how should they be presented?

CHAPTER XIX

MATURATION OF THE REPRODUCTIVE CELLS AND FERTILIZATION

How to account for individual differences in children, even in the same family—How and when inheritable variation is accomplished—The advantage of having two separate sexes—Is the “gate of gifts” closed at the time of fertilization, at birth, or later in life?—How and why each child loses fifty per cent of the inheritable traits of each parent—Why he expresses only fifty per cent of the traits he inherits from his parents—Application of known facts to the teacher’s problems.

It is a belief of long standing that the child inherits some of the traits from the father and some from the mother. Indeed, few other facts of science seem to be so universally believed. The truth that “like begets like” was assumed by all the ancients.

The compound microscope, as we have seen, was not invented until the last of the sixteenth century and was not in general use until more than two centuries later; hence people of earlier times were restricted in their knowledge of breeding and heredity to the animal and plant forms that they could readily see. In certain domesticated animals that had outstanding traits showing large variations within a given species, the trend of inheritance could be observed, and observation sometimes led to efforts toward controlling the process. Outstanding traits easily observed were color, size, shape, horns, number of offspring in a litter, and the like. Almost all of the classical writings on animal husbandry refer to the likelihood that characters found in one generation would be found also in the next generation. Many of these observations and predictions have stood the test of scientific investigation; others have been shown to be fallacious.

That both the male and the female contribute to the formation of the next generation was easily observed because of mark-

ings, size, and color; but how fertilization of the egg actually took place, and how much the offspring inherited from each parent could not be told before the invention of the compound microscope, and before many other questions were cleared up. Even to-day those not acquainted with what the microscope has revealed may be heard to say that the son inherits most of his traits from the mother and the daughter from the father. We now know that the daughter and the son have equal opportunities to inherit from each parent, and that on the average the traits shown by a boy or girl are equally divided so far as maternal and paternal origin are concerned. The facts underlying this statement have been established by a number of brilliant observers, most of whom have done their work during the past half-century.

It was the great German scientist, Weismann, who predicted in the eighties of the last century, that in some way which he did not know there must be a loss of traits to the extent of fifty per cent from each parent; otherwise each generation would have twice as much inheritance as its immediate predecessor, and all species would have been overwhelmed long ago with their superabundance of inherited traits. That the present generation is not twice as heavily endowed as the preceding one is self-evident.

The evidence to support Weismann's theory was soon forthcoming in the work of a number of prominent investigators who used the microscope as the principal instrument to carry on their research. It was Van Beneden in 1883 who first demonstrated the fact that the matured egg cells and sperm cells had only half the number of chromosomes characteristic of the somatic (bodily) cells of the species.

Before the complex process of the *maturation* of the egg and sperm cells could be understood, it was necessary that the process now called mitosis should be known and interpreted, and before either of the latter advances could be made, the idea of the cell as the unit of life had to be well in hand. In Chapter XVII the principal facts concerning the morphology of the cell and the process of mitosis, have been set forth.

Although the process of the maturation of the egg cell and sperm cell is different in some ways from mitosis, yet in some aspects there are fundamental resemblances. In both the somatic and the germ cells, mitosis takes place, but in the germ cells, the process is limited to the early stages of development. In the final stages greatly modified mitosis takes place, called maturation.

Before the individual of any species, such as a frog, bird, or mammal, becomes sexually mature, the germ cells multiply only by mitosis. By sexual maturity we mean the ability to produce healthy egg or sperm cells, which is the chief indication of adulthood. In other words, the egg cells of the female and the sperm cells of the male increase in number up to a certain point by mitosis, as do the muscle, nerve, skin, and all other cells of the body. This mitotic process continues for a considerable time,—if not, indeed, until the animal reaches sexual maturity. In species where there is a long period of infancy or immaturity, these immature sex cells may remain quite inactive for a long time following the *multiplication period*. Such cells are known as *oögonia* and *spermatogonia*. They have the same number of chromosomes as the somatic cells.

Since the maturation of the egg cell, known as *oögenesis*, is somewhat different from the maturation of the sperm cell, known as *spermatogenesis*, let us consider them separately, studying the egg-cell maturation first.

Very early in the embryonic development of the female individual, certain cells are set aside for the sole purpose of reproduction. These are known as the *primordial egg cells*. Under normal conditions these egg cells divide by the process of mitosis, resulting in several or many *oögonia*, depending upon the species considered. This period of increase in number of the primordial egg cells is known as the *multiplication period*. As soon as this process is completed, either there may ensue a relatively long dormant period or the next stage may follow soon, depending upon the species, the health of the individual, and environmental conditions.

When the female animal approaches sexual maturity, at least one of these oögonia begins to increase in size. Again species differ greatly as to the number of eggs that begin to grow at the same time. During this, the *growth period*, the number of chromosomes of the primordial egg cell (which we will arbitrarily say is four) has not increased, but only the quantity of the cytoplasm. We shall see later why this is

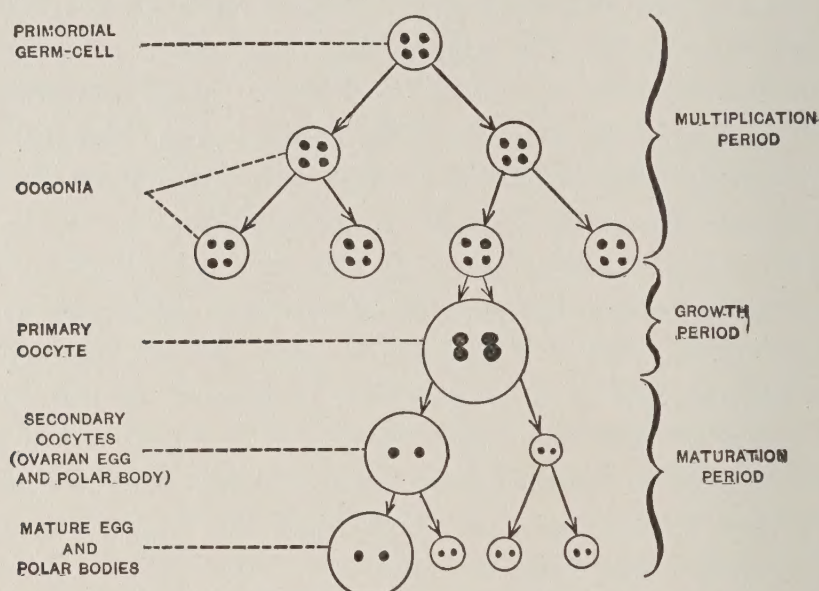


FIG. 84.—Diagram illustrating the stages of oögenesis (maturation of the egg). The primordial germ-cell is represented as possessing four chromosomes. (After Hegner.)

necessary. It should be kept in mind that each species has a definite number of chromosomes in both the germinal and the somatic cells.

When the growth period is completed, these egg cells are known as *primary oöcytes*. It is during this stage that the chromosomes unite or conjugate to form *double* or *bivalent* chromosomes. It should be kept in mind that, of the four chromosomes found in the egg cell of the female at this stage, one half are paternal in origin and one half maternal. It is likewise just as true that the immature sperm cell received half of its chromosomes from the maternal and half from the paternal

side. These bivalent or double chromosomes carry the same general traits, differing only in details, but one half came from the maternal and the other half from the paternal side.

Each primary oöcyte gives rise to two secondary oöcytes. It is during this division that the chromosomes which united to form the bivalent or double chromosomes, separate, one *single* or *univalent* chromosome going to each of the secondary oöcytes.

At this particular point the process differs markedly from that which we have described as mitosis. (See Chap. XVI.) In mitosis the entire chromosome always splits lengthwise, one half of each going to each daughter cell. There is also another great difference exhibited in the egg cell, not found in the somatic cells: in the former the cytoplasmic division is very uneven. In fact the difference in size is so marked that one part is known as the polar body and the other as the egg cell. The polar body is non-functional, although it may continue to divide, whereas the egg is functional. The polar body is formed by the egg nucleus migrating close to the surface, where a mitotic figure is formed, one end of which soon goes into the small budlike swelling, carrying with it one-half of the chromosomes. At this stage the small bud or swelling is pinched off, leaving half the number of chromosomes inside.

In a short while the egg throws off, in a manner similar to the first, a second polar body, which contains half of each chromosome. The reason for this second polar body is not known for like the first it seems to have no function. Possibly both were functional at some time in the distant past. Since the first polar body is likely to divide in the same way as the egg, at the end of oögenesis four cells have been derived from the original primordial egg cell. These four are known as the *mature egg and polar bodies*. The mature egg cell with half the number of chromosomes found in the immature egg cell is now ready to unite with a similarly matured sperm cell. This matured egg cell is known as the *female gamete*.

In a similar fashion, very early in the development of the male individual, certain cells are set aside which are destined to

undergo *spermatogenesis*. At the beginning, these early male cells are known as *primordial sperm cells*. During the growth period, which is accomplished by normal mitosis (Chap. XVI), a great number of male cells are produced, often numbering millions—no one seems to know how many are or can be produced. During this *multiplication period* these male cells are known as *spermatogonia*.

When the male animal is approaching sexual maturity, these spermatogonia increase in size and are now known as *primary*

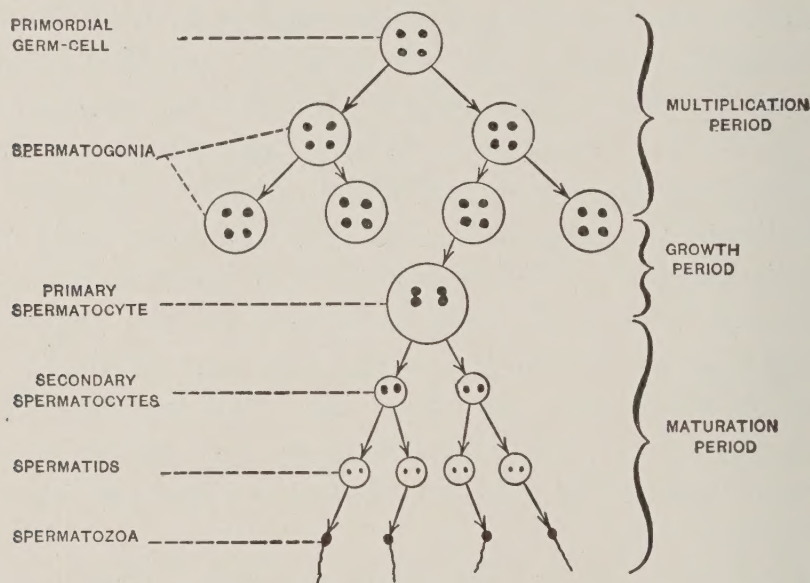


FIG. 85.—Diagram illustrating the stages of spermatogenesis (maturation of the sperm). The primordial germ-cell is represented as possessing four chromosomes. (After Hegner.)

spermatocytes. In each of these the chromosomes unite or conjugate to form *double* or *bivalent* chromosomes. At this stage each primary spermatocyte divides, giving rise to two *secondary spermatocytes*. It is during this division that the chromosomes, which united to form the double or bivalent chromosomes, separate in such a way that one *single* or *univalent* chromosome goes to each secondary spermatocyte.

Very shortly, each secondary spermatocyte divides, forming two *spermatids*. Unlike the secondary oöcytes, the secondary spermatocytes and spermatids are equal in size, and as soon as

the spermatids change into *spermatozoa* with motile tails, they are functional. That is, each of the four spermatozoa is capable of uniting with or “fertilizing” a mature egg. It will be remembered that only one of the four cells resulting from the immature egg is capable of uniting with a spermatozoön and supporting life—that is, the large egg; the other cells are the apparently functionless “polar bodies.” The matured sperm cell, the spermatozoön, is known as the *male gamete*.

Although the processes of oögenesis and spermatogenesis are slightly different so far as one important detail is concerned, yet both involve a similar and very essential change—namely, the reduction of the number of the chromosomes common to the somatic cells of that species, *diploid*, to half the normal number, *haploid*. Since the chromosomes are known to be the direct carriers of inheritance, it means that one half of the traits which each egg and sperm cell had in a dormant condition are lost to each individual. Since the lost half is due to chance, as will be shown in another chapter, each is likely to receive a different half and therefore have a different inheritance. It is here that *real fundamental inheritable variation has its first chance to be accomplished*. Thus two brothers, for example, may each have some resemblance to their parents and to one another, but neither is exactly like either parent or exactly like the other brother—unless, in the latter case, they are “identical twins,”—in which case, as we shall see, both have developed from the same egg-cell fertilized by the same spermatozoön, and thus have the same inheritance.

Fertilization, then, is accomplished by the union of the mature female egg cell with the mature male sperm cell. The product of this union is called a zygote. Sometimes the fertilization of the eggs may be on the outside of the body as in most fishes, frogs, toads; and sometimes on the inside of the body, as is typical of all reptiles, birds, and mammals.

It is of course true that even though mature eggs are regularly produced from immature ones by most healthy females, they result in adult individuals only when united with matured sperm

cells. In many species the great majority of the eggs matured never get a chance to be fertilized by the male. This is even

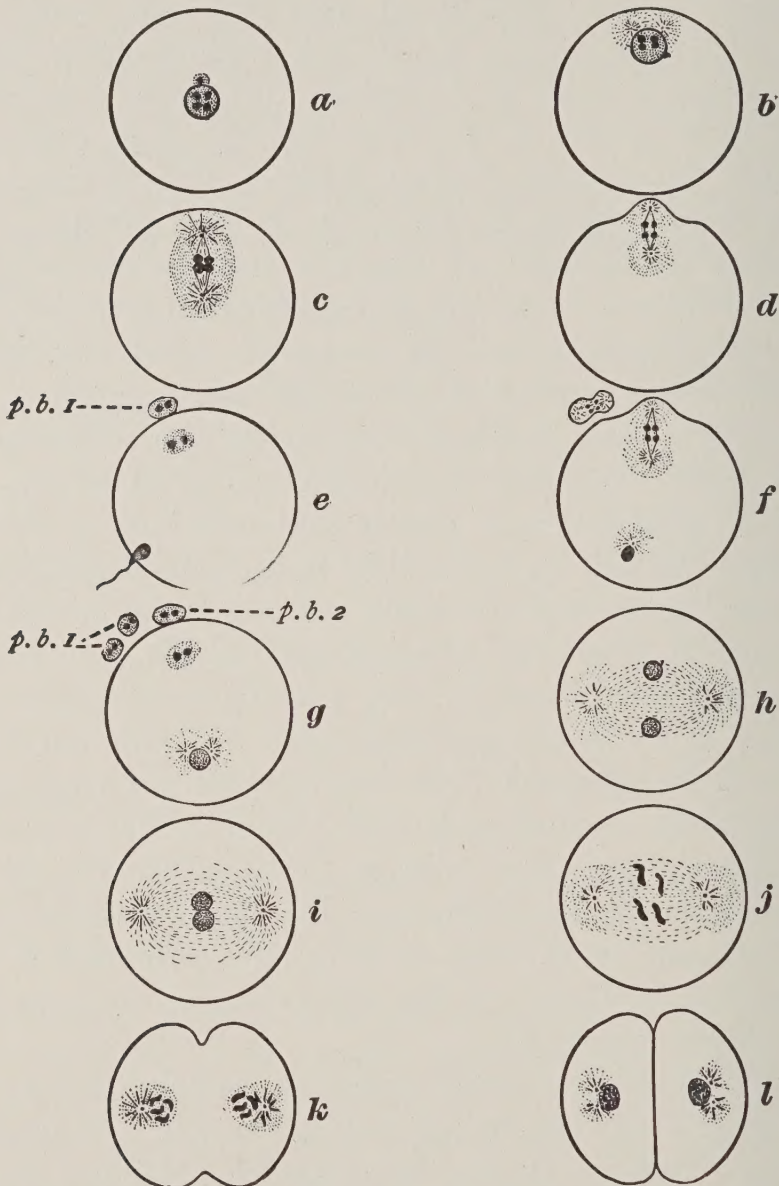


FIG. 86.—Diagrams illustrating the maturation, fertilization, and cleavage of an egg. The primordial germ-cell is represented as possessing four chromosomes. p. b. 1, first polar body; p. b. 2, second polar body. (From Hegner.)

more frequently the case with the male cells, since these, in most species, are produced in much larger quantities than are

the egg cells. Probably not one in a hundred thousand or even a million ever unites with a matured female cell.

If the opportunity presents itself, the sperm cell may enter the egg cell long before the process of oögenesis is completed. In some species, a common time for the sperm cell to enter is shortly after the first polar body has been thrown off. The union of the two nuclei, with reduced number of chromosomes, may then take place immediately, soon resulting in two daughter cells resulting from normal mitosis. These two divide into four cells, the four cells into eight, and so on following the well-known stages outlined in the chapter on embryology (Chap. XVIII).

The most important points to remember in this chapter are: (1) that chances for variation come with the maturation of the egg cell when the first polar body is thrown off, again with the maturation of the sperm cells when the secondary spermatocytes are produced, and yet a third time when fertilization takes place; and (2) that the chromosomes are reduced to one half the somatic number by the process of maturation.

Although the number of chromosomes is reduced to one half by maturation in both the egg and sperm cells, and although half of the traits from the maternal and paternal side are forever lost to each matured sex cell, yet on the union of the sperm and egg cells, the full number of chromosomes is restored. For the loss of half of the maternal and paternal traits in the female and male cells respectively, we now have a complete restoration *in quantity* of inheritance. The quality, of course, will depend upon whether the inheritance fund brought in by the male at fertilization is qualitatively equal to the inheritance fund lost by the female cell with the first polar body during maturation.

By these processes of maturation and fertilization there has been made possible the *most fundamental phenomenon of all organic nature,—inheritable variation*. We have seen in earlier chapters how fundamental variation is to the life of every species because of the ever-changing environment and because of the fact that every species must be somewhat adjusted to the changes or disappear.

The processes of maturation and fertilization in the egg cells and sperm cells of the human being are almost identical with those of other animals, particularly the mammals. The great variation that we find in human life, with no two just alike, is made possible because of the large number of chance combinations that may be made in the maturation and union of the egg and sperm cells. The human being has forty-eight chromosomes in the somatic cells; hence a very large number of different individuals might result from one marriage, if life were sufficiently long and if the female were capable of producing throughout the life period. Only identical twins are alike in inheritance, since they result from the union of the same egg and sperm cells, but even they soon become somewhat different because of the varying influence of environmental forces.

At the time when the egg cells or sperm cells begin to grow in size, at the time of the formation of the first oöcyte and spermatocyte, a great change takes place in the life of the individual. It is at this time that both boys and girls become more than ordinarily conscious that they are of a particular sex. At this stage the girl almost suddenly changes into a young lady and the boy into a young man. Since these young individuals, at the beginning of adult life, are hardly conscious of what has taken place and consequently scarcely understand themselves, it is highly important that the teacher and the parents should be aware of this critical stage. This is the beginning of the age of adolescence—of early adulthood.

It is during the seventh, eighth, and ninth grades that the majority of individuals enter this critical stage, so the junior high-school teachers and those who teach in the first year of the senior high school have a particularly important job. With some pupils it may seem best to tell them in a dignified but clear manner just what has taken place, and with some it may be better to talk less openly. The teacher (it should be the parents) will have to be very careful here to approach the subject in exactly the right way and at exactly the right time. Ordinarily the biology instructor has the best chance to give this information if he has

gained the absolute confidence of the individuals to whom he is talking. But whether the teacher does or does not undertake instruction on so delicate a subject, he or she should know that the early adolescent period is often one of very serious individual problems to boys and girls.

QUESTIONS

1. Is the law of chance, upon which individual differences largely depend, always a good thing for the individual? For the race?
2. Why is it even more important that the expectant mother be healthy than that the father of the unborn child be healthy?
3. In how many places in the process of maturation and fertilization is it possible for germinal variation to be accomplished?
4. In some insect species there are no males. Would you think that the maturation of the egg cell would be complete in these species? Why or why not?
5. Why do you think that there are in almost every species many more mature sperm cells produced than mature egg cells?
6. Are individual differences as exhibited in school children chiefly accounted for by the processes of maturation and fertilization or by the subsequent environment after birth?
7. Why is it important for all teachers to know the time of and the process of maturation and fertilization?

CHAPTER XX

THEORIES CONCERNING INHERITANCE BEFORE THE YEAR 1900

Ancient theories and beliefs—Superstitions of the past and present.

There have been perhaps more superstitions and myths connected with the subject of inheritance than with any other phase of life. In view of the difficulties that beset all efforts to solve the problem before the development of the microscope, it is not surprising that the ancients, the people of the Middle Ages, of the later centuries, and even up to and including our grandparents and parents had most marvelous and often weird explanations for the various things that happen in this field.

Doubtless in many out-of-the-way places, experiments and observations on heredity have been made by unknown men. Unless their findings are published, these observations are soon numbered with the forgotten. Had it not been for the fact that Mendel published the results of his findings, his observations would have been lost and thus a scientific basis for the study of inheritance would have been greatly delayed. As it was, Mendel's remarkable work remained unnoticed for years.

Because of a lack of scientific evidence to support either side of any particular theory of inheritance, it is not surprising that the ancients had very peculiar ideas concerning the origin of life and the relation between generations. A widespread theory of the origin of life, dating far back into unwritten history, is that of *spontaneous generation*. Although this theory originated before the dawn of the written page, it was believed by nearly everybody up to a century ago. Even during the latter half of the nineteenth century there were many who strove to uphold this theory, stubbornly resisting the proved facts of science.

The man who did most to overthrow this superstition was one of the two greatest of modern scientists, Louis Pasteur. By means of his painstaking experiments he knocked down, one by one, all the props that could be erected to support this theory.¹

A good example of how the theory of spontaneous generation was supposed to operate is this: frogs are always to be found in wet swampy places, and therefore a combination of water, air, mud, and green slime was said spontaneously to generate frogs during favorable seasons of the year. Mice likewise were thought to arise from a combination of soil, air, and grass or weed plants because they are to be found in such areas abundantly. Maggots were said to arise spontaneously from dead animals; and later on when bacteria and protozoa were discovered, they were thought to be the result of putrefaction and decay. The fact that bacteria and protozoa are the cause of decay is a much later discovery. Even to-day there are those who will maintain vigorously that the horse-hair "worm" or "snake" arises from a horse's hair dropped in water and kept there for a certain length of time.

That previous generations were ignorant of what we now consider everyday knowledge should not be interpreted as a harsh criticism of the past, particularly of the scientific men of the past. It is altogether possible that the advances made by previous generations were fully equivalent to those achieved by this generation, when due allowance is made for the facts and tools they had to work with. Scientific knowledge necessarily has advanced slowly because one branch of science has often had to wait on another branch of science for many years, or even for centuries. For example, the science of geography had to wait on the invention of the compass and the astrolabe. Microbiology had to await the compound microscope. Even after the simple lens had been invented, it took two hundred years for men to learn how to put two lenses together and thus pave the way for both the telescope and the compound microscope. Unless a student understands how difficult it is to add one new thought or

¹ See Locy, W. A., *Biology and Its Makers*, for details.

prove one new theory, he has missed one of the most important lessons that science can teach. When he understands this he is no longer arrogant over what he knows but humble because of the many things he does not know.

Perhaps the greatest mistake made by most of the ancients and even down to recent times, was the assumption that the laws governing human inheritance were totally different from those governing the other higher animals. This greatly impeded any attempt to find out the laws underlying human inheritance.

Many fantastic theories arose as to how to predict and to control the sex of the coming generation. One man is said to have collected two hundred sixty-six theories as to the various beliefs held in the past, all of which he rejected as unreliable. He then gave a theory of his own to explain the correct method of sex determination and control, only to have a fellow scientist proclaim the next day that there were now two hundred sixty-seven theories, none of them true.

We now know that the law of chance—which is really a law—determines whether the individual will be male or female. Professor W. E. Castle says that in all mammals thus far carefully studied, two kinds of sperm cells are produced, X and Y, and these in about equal numbers. Accordingly, the offspring should be about equally divided between male and female, which is about what is found to be the case. The birds, on the contrary, all seem to produce two kinds of egg cells. It is apparently true among birds, reptiles, amphibians, fish, and nearly all other forms of animal life that as many males are produced as females, and for about the same reasons as in mammals. The sex of an individual, at least in the higher forms, seems to be wholly outside the control of man.

In one of the small crustacea, however, L. A. Brown found that he could largely control the sex of the eggs by lowering or raising the temperature of the water, or by crowding a large number of individual animals into one bottle or by placing just a few in each bottle. For example, in some specimens of the genus *Cladocera*, eggs which normally would produce only females were found to

produce males almost exclusively when the temperature was lowered ten or fifteen degrees below normal during maturation.

Even though similar techniques might be found for controlling the sex of the eggs of other species, higher in the scale of life, it is improbable that the sex of mammals, including man, will ever be predetermined or controlled, since the eggs are always inside the body, entirely out of reach and away from possible control by experimenters.

Another common belief is that prenatal influences, other than the mental influences discussed in Chapter XVIII, have a decided effect on the offspring. Many different stories illustrating about the same thing are still in circulation, especially among those who have had little scientific training. A typical example is this: While the child was being carried in embryo by the mother, the latter ate far too many strawberries at one time, with the result that the child had one or more permanent red spots just the color and shape of strawberries.

While these stories are still firmly believed by many people, the evidence of biological science is clearly and emphatically against even the possibility of such influences having the alleged effects upon the offspring. There is no known mechanism for producing such changes, and the facts in practically every case can be explained in much simpler and far more reasonable ways.

Galton will be the last of the pre-Mendelian theorists to be discussed in this chapter. Strictly speaking Galton did his important work after Mendel, but most of it was published before Mendel's publications were discovered in 1900, so from the standpoint of his influence on scientific studies in heredity, Galton preceded Mendel.

Francis Galton, an outstanding English scientist and a cousin of Charles Darwin, became world-famous largely because of his studies of mass measurements. Instead of studying carefully just one or two characters of a few individuals or families, he concerned himself with the measurements of multitudes of the same species in different countries, at different ages, and under different conditions.

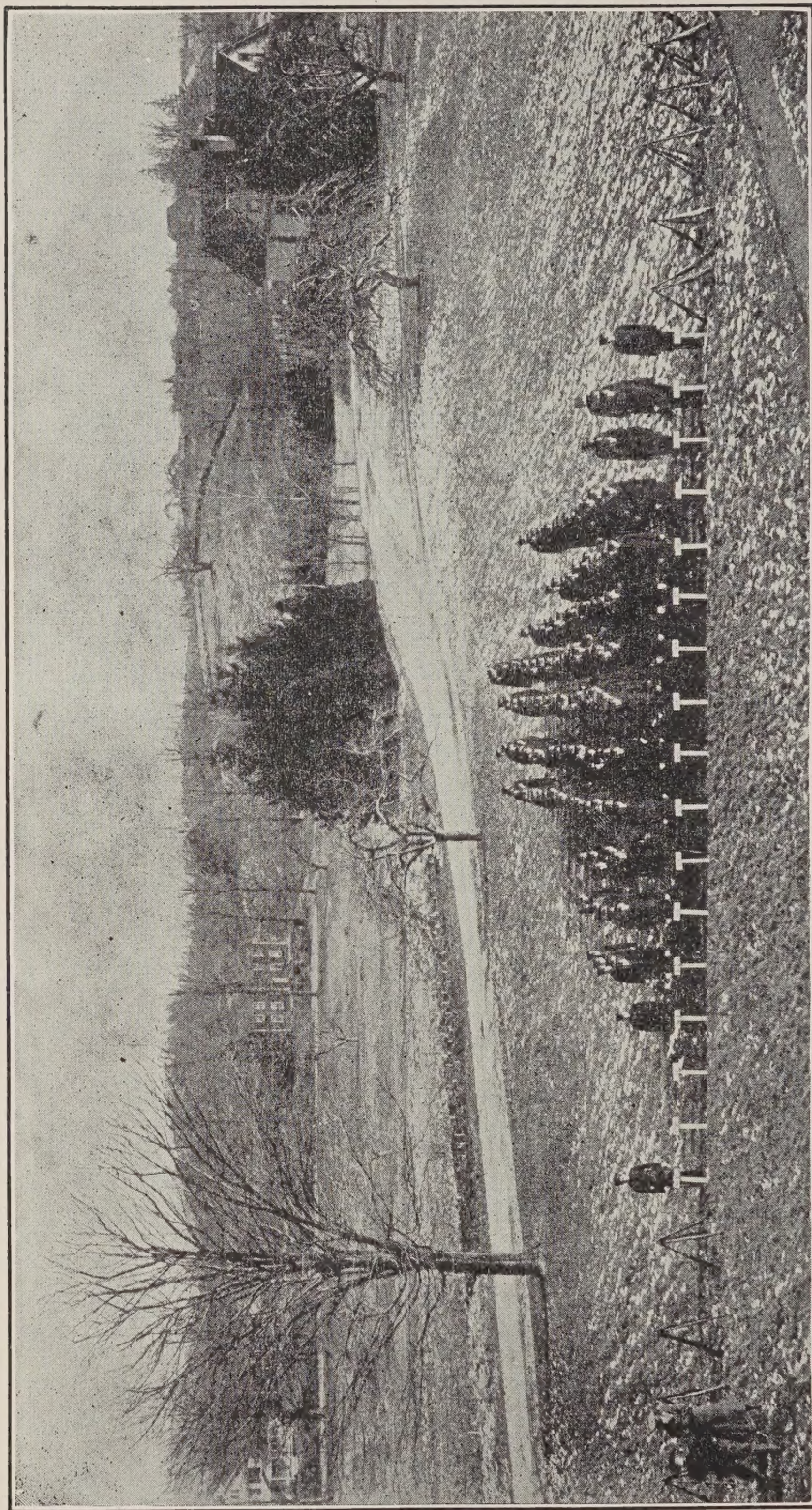


FIG. 87.—Company of students grouped according to height. The height of the men and the number of men in each file are shown by the figures below. The company constitutes what is technically known as a “population” grouped in “arrays of variates”; the middle array or file gives the median or average height of the population. If a line be drawn connecting the upper ends of each file, and another line be drawn along the front rank to serve as a base, the resulting geometric figure forms a “scheme of distribution of variates” or “variability curve,” since if the number of arrays were larger, the line joining their tops would form a perfectly smooth curve. The arrangement of homogeneous objects of any kind in such form as this is the first step in the study of variation by modern statistical methods, and on the study of variation much of the progress of genetics rests. (From Blakeslee.)

By measuring the height of numerous human beings, for example, he found that exceptionally tall parents produced offspring on the average slightly shorter than the parents themselves, and that the extremely small parents on the average, had offspring slightly taller than themselves. The tendency of the descendants of extreme variants to return to the average of the population seems ever to be present, whether the character be height, weight, or mentality. It is almost as though nature were trying to keep the majority of individuals on the grade of the average.¹ This law, worked out by Galton, is sometimes called the *law of regression*.

Another observation, sometimes called *Galton's law of inheritance*, is that children tend to inherit one half of their characters from their immediate parents, one fourth from their grandparents (four), one eighth from their great-grandparents (eight), and so on. This law of course is not entirely accurate but expresses a fairly common tendency.

QUESTIONS

1. Why do you think many persons attempt to give explanations for the observed facts of inheritance, even when the answers are mere superstitions, rather than holding their judgment in abeyance while awaiting more facts?

2. Why did people formerly believe in spontaneous generation?

3. Do you think it would be a good thing if we could control the sex of unborn animals? Of man?

4. Why is it a good thing that mental prenatal influences in all probability do not affect the inheritance fund of the unborn child?

5. How do you account for the fact that in animals including man there is a tendency for each generation to return to the average size, weight, and native intelligence of the species?

6. Why is Galton's law a poorer measuring-stick to use when dealing with individuals than with groups?

7. What myths or superstitions concerning prenatal influences and inheritances did you hear about when you were growing up? Are any of them true and, if so, why?

8. What facts, if any, brought out in this chapter could be profitably taught in the elementary grades? The junior high school? The senior high school?

9. If there are such facts, what would be the value of teaching them?

¹Of course this tendency is being continually counterbalanced by the new variations made possible by the processes of maturation and fertilization.

CHAPTER XXI

MENDEL'S LAWS OF INHERITANCE

The original fundamental Mendelian concepts or laws—Recent contributions to Mendel's laws—Do the maternal and paternal traits blend to form the offspring or are separate small units inherited unblended from each parent—Apparent exceptions to Mendel's laws.

Gregor Mendel was born in the year 1822, and at the time of his outstanding experiments he was the abbot of a monastery in Brünn, Austria (now Brno, Czechoslovakia). Although trained for the priesthood, he had developed the scientific trait of experimenting and recording his findings accurately.

It was during the years 1861–1866 that he experimented in his cloister gardens chiefly on the color and form of peas, publishing the accounts of his experiments in 1866 and 1867 after reading his papers before the Natural History Society of Brünn. The results of his experiments doubtless attracted some attention in the neighborhood of the cloister, but for several reasons his work lay buried in the library, until rediscovered by three men almost simultaneously, in the year 1900. This latter year then can be said to mark the beginning of the scientific era in scientific plant and animal breeding, although technically one could say that it started in 1861. It is most unfortunate that Mendel did not attract the attention of other workers in biology then living, such as Darwin, Pasteur, Wallace, and Huxley. Darwin's *Origin of Species*, was published in 1859, and became at once the subject of much controversy. Darwin and his associates would have been eager to learn of Mendel's findings and they and the public would have profited much had this acquaintance been made. Mendel's results had been duly recorded and published, but their very great significance was not clearly appreciated by the few who read the report at the time. It was most fortunate that

the record was preserved, but unfortunate that it remained for so long a time unnoticed.

In his experiments on peas Mendel was most careful to send to the old and well-established seed houses of Europe to secure tried and tested seeds known as "pure" seeds. A pure seed, then as now, would always produce a certain well-known result

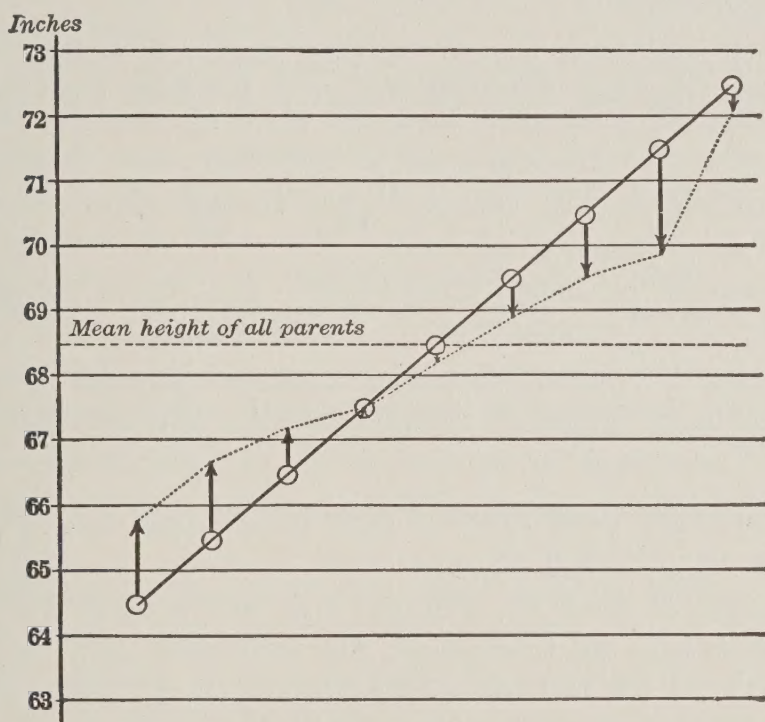


FIG. 88.—Scheme to illustrate Galton's "Law of Regression." The circles represent graded groups of parent height, while the arrow points indicate the average heights attained by the respective offspring. The offspring of the undersized parents are taller, and of the oversized parents are shorter than their respective parents. Based on data from Galton. (From Lindsey, after Walter.)

that could be depended on year after year. This particular fact serves to indicate how careful Mendel was to start his experiments in the right way.

During Mendel's life everybody believed that if one crossed a tall variety of plant or animal with the short, the progeny of the first hybrid generation would be intermediate in height. Not only was it generally believed that the progeny of tall and short

parents would all be intermediate between the parents in size, but that the offspring would tend to approximate the mid-position in color, weight, amount of "fuzz" on plants, hair on animals, and other inheritable qualities. It was thought that the germ plasm of the two parents would mix and therefore would produce offspring in between the two, as regards any given character.

Imagine the shock that came to scientific men when it was announced that the offspring of a cross between pure tall peas

$$\frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \frac{1}{32} + \dots = 1$$

Parents	Grand Parents	Great Grand Parents	Great Great Grand Parents	Great Great Great Grand Parents	Total Inheritance
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FIG. 89.—Galton's "Law," illustrating mathematically the approximate amount of inheritance one receives from the many generations of his ancestors.

and pure dwarf peas resulted only in tall peas the first year, that is, in the first hybrid generation.

As a careful scientist, Mendel was not content to let the experiment stop at this point. He took the peas that were produced from the tall and dwarf parents, the F_1 (first hybrid or first *filial*) generation, planted them by themselves in a separate corner of the garden, and secured even more amazing results. Approximately three-fourths of the pea vines were found to be tall, and about one-fourth were short in the F_2 generation.

Once again he had the insight to carry the experiment further by planting the tall peas resulting from the second cross, the F_2 generation, in one corner of the cloister gardens, and the dwarf peas in another locality. A third amazing thing happened. The dwarf peas obtained from the second cross bred true to type, just as true as did the original pure dwarf peas obtained from the seed houses. Never did the tall variety make its appearance from a planting of the supposedly mixed dwarf peas. The tall peas, however, when crossed among themselves, in the third

filial generation, F_3 , produced both tall and dwarf vines in a general proportion of three tall to one dwarf, as was the case in the second filial generation. A little later it was discovered that one-third of the tall peas, if given a chance, would breed true to type, producing only pure tall peas, and that two-thirds of those appearing tall would produce in the next generation the regular three-to-one ratio.

Not only did Mendel cross tall and dwarf peas but also yellow and green peas, referring to the color of the seed coat, and round and wrinkled peas, referring to the condition of the seed coat.

He thus clearly showed that, in certain peas at least, instead of a mixing of traits there was rather the appearance in the first filial generation of the "dominant" character of one of the parents. The character that does not appear in the first filial generation is called the *recessive* in contrast with the persistent or *dominant* character. This behavior is sometimes called the "law of dominance." It should be kept in mind that there are now known to be a number of minor or apparent exceptions to this "law."

The second fundamental law, which Mendel discovered and which in some ways might really be spoken of as a part of the law of dominance, is that the inheritance funds are carried in units. This is referred to as the "law of unit characters." That is, characters are inherited as units by the next generation, and do not mix with the like or similar characters from the opposite parent. These unit characters are now known often to be made up of smaller divisions, commonly called *genes*.

The third fundamental law discovered by Mendel is often termed the "law of segregation." This is illustrated in the second filial generation where, in the cross between tall and dwarf peas, the latter reappear in one-fourth of the cases. Traits may be recessive in one generation, only to reappear as distinct units in the next generation. This means that no true mixing of the protoplasm has taken place, even though the trait was apparently lost for one or more generations.

Mendel's original laws have been found to hold true in the

main, although slight modifications have had to be made in the formulation particularly of the law of dominance and the law of unit characters. Students of heredity now generally speak of the gene rather than the unit character as the inheritance unit. In addition to these three original Mendelian laws, other important principles have been discovered which will be explained later in this chapter.

It was unfortunate for Mendel that no scientist of his day was able to grasp the great significance of his work. He was handicapped also by the fact that very little was known about cells and particularly the sex cells. In the years following 1883 (Mendel died in 1884), when Van Beneden discovered the process of the reduction of the chromosomes in the egg and sperm cells to one half the somatic number (see Chapter XIX), the reason for the results of Mendel's experiments could have been readily explained. Since his work lay dormant until 1900, however, no use could be made of the idea of the maturation of the egg cells and sperm cells to interpret Mendel's laws during these seventeen years. For all practical purposes Mendel's discoveries did not exist until the year 1900. One who studies carefully the results obtained by Mendel in his hybrid crosses of peas and the process of maturation as revealed by Van Beneden at once notices that the latter seem to fit in perfectly with the former. In other words, the mechanism and behavior of the chromosomes and the maturation and fertilization of the sex cells explain satisfactorily the ratios obtained in Mendel's experiments on crossing peas.

In order to make this readily understandable, we shall diagram what happens when one crosses tall and dwarf peas, and then show how this harmonizes with what takes place at the maturation of the egg and sperm cells.

Since tallness is known to be dominant in peas over dwarfness in the F_1 (first filial) generation, we shall designate it by a capital T and correspondingly designate the dwarfness by the small letter d . Thus the original pure types of peas are TT and dd . One should keep in mind that a "pure-blooded" animal of

any kind is homozygous, or "double-dosed," for any given trait; one part (half) came from the paternal side, and the other part (half) from the maternal side. If heterozygous, then a different variation of each trait came from each parent.

Expressing the above diagrammatically we have:

$TT \times dd = TT$ in appearance, but actually Td .

This is what we find in the F_1 generation.

In the F_2 generation we have:

$Td \times Td = TT$ and dd in appearance in the ratio of 3 to 1, but actually $TT + Td + dd$ in the ratio of 1:2:1.

Thus we have:

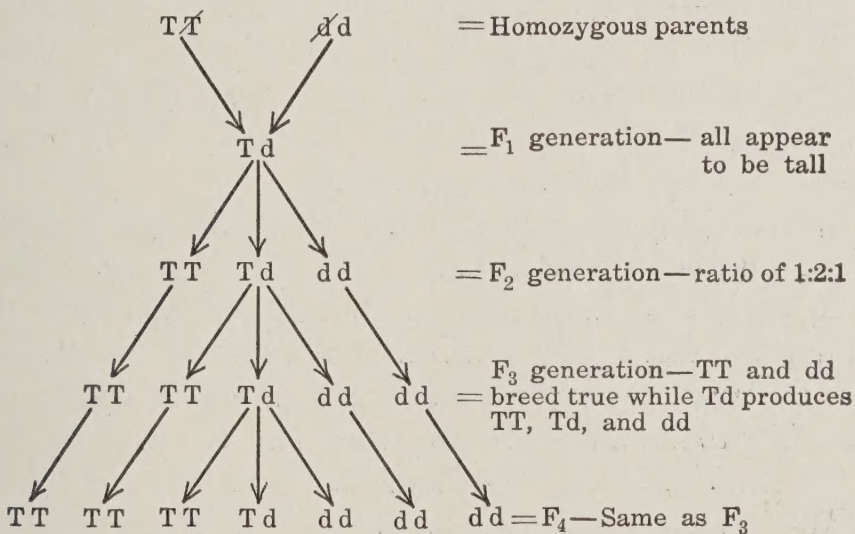


FIG. 90.—Illustrating the general Mendelian formula for a monohybrid. Line through T and d of homozygous parents indicates maturation reduction.

Now the reason for the above behavior in F_2 can probably be explained better by the following diagram:

		Male gametes	
		T	d
Female gametes	T	TT	Td
	d	dT	dd

FIG. 91.

		Male gametes	
		T	T
Female gametes	T	TT	TT
	T	TT	TT

This diagram is worked according to the law of chance. Each gamete of the male and female is given an equal opportunity to mate with each of the gametes of the opposite sex. On first observation it appears that we have four kinds of *zygotes*, but

closer study reveals that *Td* and *dT* are just alike and thus the ratio is really 1:2:1.

On the other hand the *TT* and *dd* of F_2 will produce only pure types, diagramed as in Fig. 92.

It is fairly easy to understand the diagrams shown herewith. Since there is only one factor involved (tallness or dwarfness),

both sexes are homozygous or “double-dosed” and the offspring will be always of pure type, regardless of what chromosomes from either sex are thrown off in the maturation of the egg cells and sperm cells.

By careful study one may also understand the square diagram depicting crosses between *Td* and *Td*. There it is necessary to bring in the laws of maturation in the egg cells and sperm cells (see Chapter XIX). The fundamental point to remember is that in maturation each sex cell, whether egg or sperm, loses half of its chromosomes and therefore half of its traits. Since only one homozygous or “double-dosed” trait is involved here, either the *T* or the *d* is thrown off and lost half of the time. This is true for both sexes. According to the law of chance, by giving each gamete *T* or *d* an equal chance on the average, the result will necessarily be 1:2:1. This gives each male gamete two chances to mate with the female gametes, which in the average of cases will be once for *T* and once for *d*. Or if one wishes to express it the other way, each female gamete gets a chance to mate with the male gametes, which in the average of cases will be once for *T* and once for *d*.

If one wishes to test the operation of this law of chance, it may be easily done by taking four marbles of the same size, and marking two of them with the capital *T* and two with the small letter *d*. Place these marbles in a hat, shake them as dice, and

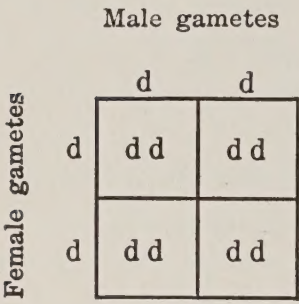


FIG. 92.

then let a blindfolded person pick out two each time. Out of a hundred draws, there will be approximately 25 TT , 50 Td , and 25 dd . This obviously is the ratio 1:2:1.

Mendel's law, then, operates according to the law of chance (not the gambler's law where there is little or no chance). In dealing with one character, such as tallness *versus* dwarfness, each gamete gets a chance to mate fifty per cent of the time, and fifty per cent of the time it is thrown off in the polar body of the egg (female) cell or is to be found in another male cell with the alternative chromosomes. While Mendel found the ratio of 1:2:1 in his cross of tall and dwarf peas in the F_1 generation as a pure matter of chance, the chance was a fair and equal one for each gamete to remain in the germ cells (that is, to be expressed) or to be unexpressed because thrown out during the maturation processes.

The reason why the ratio appears to be 3:1 in the F_1 generation is that, whether heterozygous or homozygous, the character of tallness will appear. Only one "dose" of tallness is necessary in a zygote in order to express itself because T is dominant, whereas the recessive trait must be homozygous, "double-dosed" in order to show. A recessive trait that finds expression is, therefore, always "pure," which means that it is homozygous; but a dominant trait may be either homozygous or heterozygous. In appearance the latter is just like the former and its exact germinal constitution can be determined only in the next generation by breeding back to the recessive. If in this cross some recessives appear, one knows that this dominant was heterozygous; whereas if the dominant is homozygous, no recessives will appear in the first filial generation.

By substituting the characters "smooth" and "wrinkled" or "yellow" and "green" for "tallness" and "dwarfness," the same results and proportions will be obtained. A long list of breeding experiments has been undertaken with many animals and plants to determine which trait is dominant and which recessive. Some of the findings of these experiments are the following:

Cattle	Hornlessness	dominant over	horned condition.
Horses	Trotting gait	" "	pacing gait.
Barley	Beardlessness	" "	beardedness.
Salamander	Dark color	" "	light color.
Silkworm	Yellow cocoon	" "	white cocoon.
Maize	Round, starchy kernel	" "	wrinkled, sugary kernel.
Wheat	Susceptibility to rust	" "	immunity to rust.
Canaries	Crested head	" "	plain head.
Guinea-pig	Short hair	" "	angora hair.
Mice	Normal movement	" "	waltzing movement.
Man	Brunette type	" "	blond type.

Thus far we have dealt only with one unit character, commonly called in genetic circles, a *monohybrid*. In *dihybrid* crosses, where two unit characters are concerned, the situation is a little more complex but just as orderly when interpreted in the light of our knowledge of Mendel's law and of maturation. For such a cross we shall use the unit characters Tall *vs.* dwarf (*T* and *d*) and Round *vs.* wrinkled (*R* and *w*). For some reason as yet un-

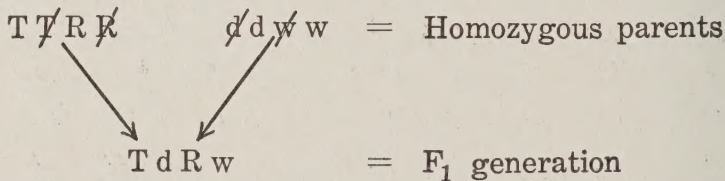


FIG. 93.—Lines through *T*, *R*, *d*, and *w* of homozygous parents indicate maturation reduction.

known, roundness of the seed coat of the pea is dominant over the wrinkled condition, just as tallness of the vine is dominant over dwarfness. In other words, we now have one pea that is tall-vined with a round seed, known to be pure for generations, homozygous, and another that is dwarf-vined with a wrinkled seed, also homozygous. This means that regardless of which chromosomes are lost in the process of maturation, the same characters remain and are expressed in the next generation, the peas looking just like the parents from the seed of which they came. Their germinal constitutions are *TTRR* and *ddww*.

On crossing tall round peas, *TR*, with dwarf wrinkled peas, *dw*, in the F_1 generation we find that all the peas appear to be

TRTR but actually are *TdRw*, with dwarfness and wrinkledness recessive. In the second filial generation, however, we have a somewhat different result from that which we found when dealing with a monohybrid. In the monohybrid only two different kinds of gametes are possible in the F_1 generation in each sex—namely, *T* and *w*, resulting, when crossed with like individuals, in four zygotes, *TT*, *Tw*, *wT*, and *ww*, the middle two of which are alike in germinal constitution. Three out of four of these individuals appear to be of the dominant character, Tall, but actually only one third of them are homozygous.

In the case of dihybrids we find that in the F_1 generation four different kinds of gametes in each sex are possible, namely, *TR*, *Tw*, *dR*, and *dw*, resulting when crossed with like individuals in sixteen zygotes, nine of which appear to be *TR*, three of which appear to be *Tw*, three of which appear to be *dR*, and one of which appears to be and is *dw*. Of the nine that appear to be *TR*, only one is homozygous; of the three that appear to be *Tw*, only one is homozygous; of the three that appear to be *dR*, only one is homozygous; and, as stated, the one *dw* zygote is homozygous.

Thus we see that out of the sixteen zygotes produced in the F_2 generation, only two are identical in germinal constitution with the individuals with which this experiment started before hybridization.

Individuals that appear to be alike, regardless of their actual germinal content, belong to one *phenotype*. In this dihybrid cross we find four phenotypes, which appear as *TR*, *Tw*, *dR*, and *dw*. Those that are actually alike in germinal make-up constitute one *genotype*. It is thus evident that there may be a number of genotypes in one phenotype. In this cross, nine of the result-

		Male gametes			
		<i>TR</i>	<i>Tw</i>	<i>dR</i>	<i>dw</i>
Female gametes	<i>TR</i>	<i>TR</i> <i>TR</i> ✓	<i>TR</i> <i>Tw</i>	<i>TR</i> <i>dR</i>	<i>TR</i> <i>dw</i>
	<i>Tw</i>	<i>Tw</i> <i>TR</i>	<i>Tw</i> <i>Tw</i> ✓	<i>Tw</i> <i>dR</i>	<i>Tw</i> <i>dw</i>
	<i>dR</i>	<i>dR</i> <i>TR</i>	<i>dR</i> <i>Tw</i>	<i>dR</i> <i>dR</i> ✓	<i>dR</i> <i>dw</i>
	<i>dw</i>	<i>dw</i> <i>TR</i>	<i>dw</i> <i>Tw</i>	<i>dw</i> <i>dR</i>	<i>dw</i> <i>dw</i> ✓

FIG. 94.

ing zygotes belong to the same phenotype, three each to two others, and one to still another.

Even more wonderful than the fact that the original zygotes can be recovered unchanged in the F_2 generation is the fact that *in a dihybrid cross, two entirely new varieties are produced* which will breed true to type if given a chance. In this dihybrid cross the two new varieties are $TTww$ and $ddRR$. The fact that they will breed true to type means that both male and female gametes brought into the zygote the same characters.

It should be emphasized that many of the numerous varieties, and even species themselves, if isolated for long periods, could have been produced in this way, and that new varieties of plants and animals can be produced almost at will by the scientific breeder whenever it is possible to find a species with two or more traits that breed true. Doubtless many of the new types produced by Burbank and other breeders and experimenters resulted more or less by accident according to well-known dihybrid or trihybrid laws.

A *trihybrid* cross behaves much the same as a dihybrid cross except that eight different kinds of gametes are possible for each sex, with a total of sixty-four zygotes, and that six new varieties are produced instead of the two found in the dihybrids.

Expressed diagrammatically, a dihybrid cross appears in Fig. 94:

The four possible gametes are TR , Tw , dR , dw .

The four homozygous individuals have a $\checkmark$ mark in the lower right-hand corner, while the two new homozygous varieties have an x mark in the lower left corner.

It is interesting to note that some of the better seed houses of the country now employ specialists in the science of heredity to produce new varieties of tomatoes, corn, peas, and other plants. The majority of the new varieties, it should be noted, are not homozygous and therefore will not breed true, producing the desired type of individual only the one generation. For this reason, in most cases, the process must be repeated each generation, and therefore those who grow the desired crop must usually buy new

seed each year from the seed houses if they desire only a certain type of product.

Since the discovery of Mendel's records, many scientists have experimented with many different species; and some of them have found that in certain species, there are certain modifications of Mendel's law, and that certain additional laws should be added to those originally formulated.

Perhaps the most common type of modification is that called *incomplete dominance*, expressed in the famous cross between white and red four-o'clock flowers. Red is known to be the dominant character, but this dominant does not re-appear until the

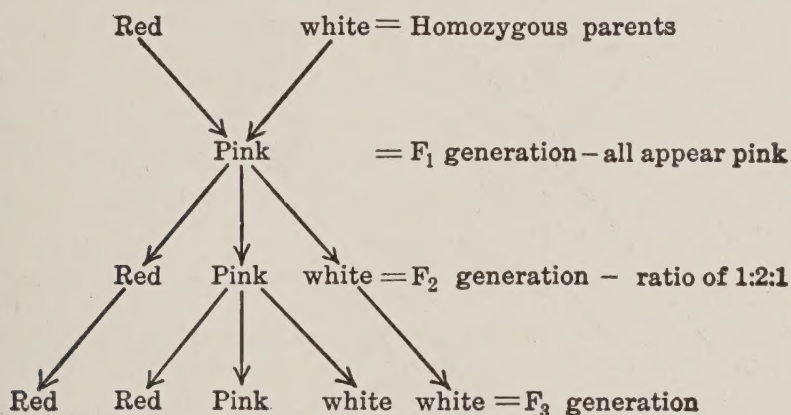


FIG. 95.

F₂ generation, when it is found in only one fourth of the cases. In the F₁ generation all of the flowers are pink, instead of red as would be expected. The pink flowers, however, yield in the next generation a ratio of 1:2:1. That is, 25 per cent are red, 50 per cent pink, and 25 per cent white. The red and white flowers breed true to type, whereas the pink flowers continue to produce each generation in the ratio of 1:2:1.

It is difficult to give an explanation for the production of the pink flower, except to say that in some way the red color is inhibited in the F₁ generation—thinned out, as it were. It is most important that the red and white characters did not really mix in the F₁ generation, but remained segregated; otherwise there could be no pure red and white flowers in the F₂ generation.

Another example of incomplete dominance is found in the blue Andalusian chicken. In order to produce blue Andalusians the parental stock must be white on one side and black on the other, but this blue condition will not breed true except in fifty per cent of the cases in the F_2 generation; so if one wishes to get a hundred per cent blue Andalusian chickens one must use pure white and pure black stock each generation for breeders.

Another apparent exception to Mendel's law is formulated in the *X chromosome hypothesis*. Certain investigators found that instead of having only one kind of matured sperm cell, certain species produce two kinds. At first it was thought (erroneously)

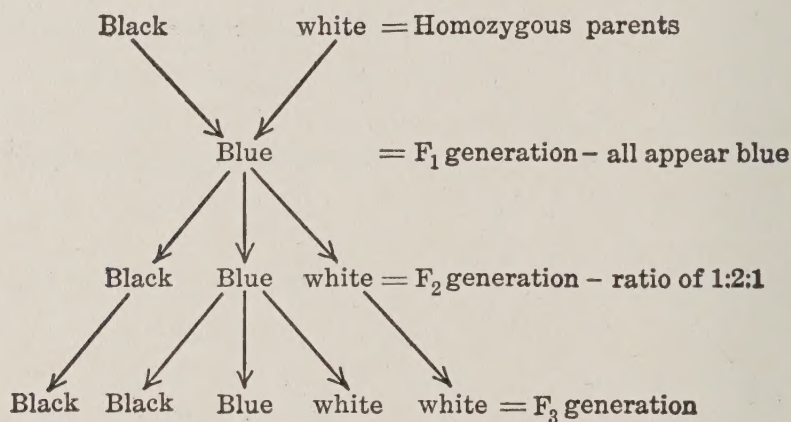


FIG. 96.

that a totally different or odd chromosome had been found, hence possibly the reason for the term "X chromosome." Even though a poor one, the name is still used and probably always will be. It was subsequently found that in some species, a matured sperm cell having the same number of chromosomes as the matured egg cell produces a female, whereas the matured sperm cell having one less than the number in the matured egg cell produces a male.

There is no known reason why some species should have two kinds of sperm cells so far as sex is concerned. This is one more of the many facts of nature so far unexplained.

The principle of *sex-linked inheritance* is another addition to the original laws of Mendel. Here certain traits are almost al-

ways found in one sex and rarely in the other. A good example is that of color-blindness in the human being, which occurs in the male much more frequently than in the female. According to Morgan, "A color-blind father transmits through his daughters his peculiarity to half of his grandsons, but to none of his granddaughters." In order to explain sex-linked inheritance satisfactorily, one apparently must assume that two kinds of sperm cells are produced by a species. In one kind of sperm cell the character in question is present and in the other it is not. To be expressed by the female the individual must be homozygous for this trait, but it is only necessary for the male to be heterozy-

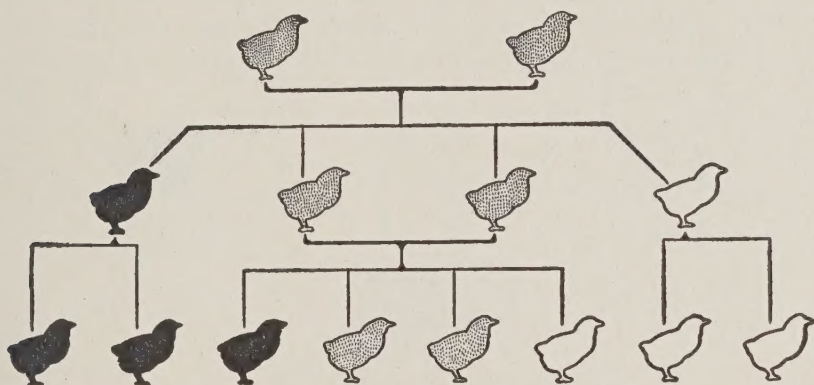


FIG. 97.—*Color inheritance in the Blue Andalusian fowl.* When good specimens of this variety are mated, their offspring produce on the average only 50 per cent of good Andalusian Blues; the rest are about evenly divided between white chickens and black chickens. The Blue Andalusian is a hybrid; the only way to get 100 per cent of birds of this kind is to mate a white and a black parent. (From Jewett's *The Next Generation*, by permission of Ginn and Company, publishers.)

gous for this trait in order that it be expressed. It is interesting to note that the male of the human species has been recently found to have two kinds of sperm cells, and this fact is consistent with the frequency with which relative color-blindness is found in men and in women.

Linkage is an important principle discovered since Mendel's experiments. In the painstaking work of Professor T. H. Morgan and his students at Columbia University, now extending over a period of about seventeen years, it has been found rather

definitely that certain characters in the common fruit fly, *Drosophila melanogaster*, are carried in certain chromosomes and even in certain definitely known parts of the chromosomes. At least the hypothesis advanced agrees exactly with the results obtained.

The linkage phenomenon is made possible, according to this hypothesis, shortly before the maturation of the egg and sperm cells. In certain species some of the paired chromosomes wind or twist about each other more or less, and it is thought that upon separation the chromosomes do not unwind as at the time of maturation. To use the diagram, the chromosomes *abcd* and *a'b'c'd'* on separation after pairing of chromosomes (synapsis)

White sweet pea with color
factor but no pigment



White sweet pea with pigment
but no color factor



Purple sweet pea possessing
color factor and pigment

FIG. 98.

are constituted *abc'd'* and *a'b'cd* respectively, (the lower half of each chromosome exchanging places), instead of *abcd* and *a'b'c'd'* as expected.

Sometimes the chromosomes wind tightly about each other several times and then again there may be but little loose winding or none at all. It is easy to understand that the characters which are close together in a chromosome before synapsis (pairing of chromosomes) would be more likely to remain in the chromosome after synapsis than would two characters farther apart. Thus *a* and *b* would be more likely to remain in the same chromosome after synapsis than *a* and *c*. If one can measure the length of the chromosome concerned, a rather accurate mathematical calculation can be made as to how often characters lo-

cated at certain places in a chromosome will be in the same chromosome after synapsis. If one takes a piece of crayon on which at regular intervals is marked *abcd* and then drops the crayon to the floor, breaking it, one will get a rough idea as to the working of this law. Obviously *a* and *b* will be more often in the same broken piece than *a* and *c* and in turn *a* and *c* are more likely to be in the same piece after falling than *a* and *d*. In fact *a* and *d* will be in the same piece only if the crayon does not fragment, which is analogous to the chromosomes separating after synapsis just as they entered.

We thus see that the three principles or "laws" worked out by Mendel in the years 1861–1866 still hold in the main, but

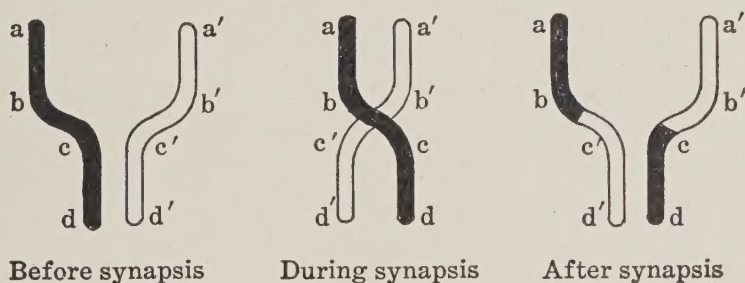


FIG. 99.

that certain modifications have been found and that several additional laws have been discovered. Perhaps the greatest modifications are that the word *gene* must be used nearly always in place of the words *unit character* and that *linkage* is of common occurrence. The former term has been found to be too large. What was once referred to as a unit character is now known to include from several to many genes which in some species may be inherited independently. The possibility of such independent inheritance is readily explained by the linkage hypothesis. Mendel was particularly fortunate in the selection of the species that he experimented upon and the characters selected, else he might have obtained quite puzzling results, impossible of tabulation and explanation with the then known facts concerning heredity. The traits selected fortunately behaved as unit characters, not breaking up into separate genes.

In the next chapter will be discussed the more important facts known concerning human inheritance.

QUESTIONS

1. Why do you think that before Mendel's day, it was a general belief that the progeny of a cross between pure tall and pure dwarf peas would be medium in height?

2. If pure brown eyes are dominant over pure blue eyes, how is it possible in America that we still have pure blue eyes?

3. Assuming that in the distant future all the races of the world will become thoroughly mixed and fused, what percentage of the population will have blue eyes?

4. Have you any theory as to why one trait is dominant over another trait? Any basis for the theory?

5. Would it be possible to produce new species (not varieties) by means of Mendelian crosses?

6. If white people and Negroes differ on ten important traits, what chance would there be for the offspring of such crosses to possess only pure white traits?

7. What do you think is the most important thing that scientists, by using the available knowledge concerning Mendelian laws, could do for the human race?

8. Mendel's law is easily the most important biological discovery of the last generation. In your judgment should everyone who can possibly understand this law become acquainted with it? Why or why not?

9. If your answer is in the affirmative, where in the school program should this law be introduced?

10. Can you think of any ways by which Mendel's laws would be made clear to immature minds?

CHAPTER XXII

HUMAN INHERITANCE

Inheritance of eye color, hair color, feeble-mindedness, insanity, epilepsy, deafness, genius, normal-mindedness—Known facts and well-substantiated theories of inheritance.

There are two reasons why there is a widely spread interest in the subject of inheritance at the present time. The first is the possibility of the improvement of domesticated plants and animals, to bring increased economic returns or to produce greater beauty or usefulness; the second is the possibility of producing a better race of human beings—which means first of all better children. It is for the second reason chiefly that students of education are so greatly interested in the subject of heredity; and coupled with it is the possibility that the laws of heredity may throw needed light on the differences among individuals which give rise to such serious educational problems.

The known facts concerning human inheritance are far fewer than those concerning many other species of plants and animals. The reasons for the comparative dearth of exact information are: (1) few people can be sure of their exact germinal constitution, since there has been so much mixing of different stocks and nationalities; (2) few people have been willing to be used as material for experimentation; and (3) the average "human generation" is so long (twenty-five to thirty years) as to make difficult the observations and experiments that have given us so much information regarding heredity in plants and in the lower animal forms.

In pursuing the first reason further we find that, although we now have well-defined nationalities so far as geographical boundaries and cultural traits are concerned, the individuals

that make up most nations are greatly mixed in their germinal constitution. Probably the purest nationalities that exist to-day as modern nations are the Scandinavian peoples living in Norway, Sweden, and Denmark, but even here there has been some mixing with other nationalities, notably in southern Denmark. It should be added that there are many racial tribes, not organized as nations, such as Indians and Negroes, that are largely "pure" varieties—homozygous—yet even among these we sometimes find hybrids, if white or other civilized individuals have entered the area.

The English race is a good example of one of our oldest and best-known nationalities, where the national spirit is relatively high and where the boundaries are well defined. But in the make-up of most Englishmen are to be found a large amount of Anglo-Saxon blood, some Scandinavian, some German, some Scotch, some French, and a large number of minor nationalities. The German nation is also a composite of different racial stocks.

Therefore in studying scientifically the inheritance of any given person, even though he be apparently a "pure" Englishman, Frenchman, German, it is almost impossible to be sure that the subject is homozygous for a given trait, unless that trait is known to be recessive. A person calling himself an American is almost sure to be even more mixed as regards germinal make-up than even the above-named nationalities, since there has been so much immigration to this country from so many different nations and so much intermarrying. This mixture is the more likely if the American is of the second, third, or fourth generation of the immigrant stock. For this reason anyone dealing with inheritance in America has to be very careful in stating and particularly in interpreting his facts.

In pursuing the second reason for the dearth of information on human inheritance, it is not difficult to understand why few people have been willing to be used for experimental purposes, even for studying so important a topic as human heredity—in many ways the most important of all topics.

The third reason for the scarcity of information on inheri-

tance in man, the length of the average human generation, is also easily understood. Man is one of the slowest-breeding forms of life, with relatively few offspring each generation. Since Mendel's law was rediscovered as late as 1900, it is evident that careful and exact data concerning human inheritance have been collected for barely one generation. In fact the time is less than that, since little was done in the scientific study of inheritance before the year 1910. The more rapid-breeding animals have consequently been used in the study of heredity, since many of them produce a generation in about one year, and some of them, such as *Drosophila* (the common fruit fly) as many as twenty or more generations a year.

Lacking an absolutely accurate record for many generations back, as we have for many animals and plants, the data collected about human inheritance have been limited chiefly to information given by interested persons who knew something, more or less accurately, of the inheritance fund of the persons discussed.

It is a common observation that pure-blooded Scandinavian children are nearly always blue-eyed and that pure-blooded Italian children, particularly from Southern Italy, are nearly always brown-eyed. The reason for this is readily understood since the parents of these children are nearly always found to be blue-eyed or brown-eyed respectively. In other words the parents are homozygous for eye color, and are unable to transmit something to their offspring not found in their own germ plasm.

Expressed in terms of maturation, we find that, regardless of which one of the double or bivalent chromosomes is thrown off at reduction, the same trait remains. In fact, that is what we mean by "pure-blooded" types. A mongrel or hybrid, on the other hand, may produce a variety of traits, because the paired or double chromosomes are not identical in germinal constitution.

Then if we take a cross between a blue-eyed homozygous Scandinavian and a brown-eyed homozygous Italian, all the children of this F_1 generation will be brown-eyed, since brown is dominant over blue, and therefore when blue is expressed, we

Eye-color preference is purely a matter of taste, with no known advantage to either type.¹

Occasionally a person will say that he knows of an exception to the rule that blue-eyed parents can have only blue-eyed offspring. So far as it is known, such cases can always be satisfactorily explained by an eye-color expert. For example, the person may be green or grey-eyed, which really are varieties of blue eye. Sometimes the bluish eye has heavy brown specks in it and is genetically considered a brown eye. There seems to be no well-authenticated case of blue-eyed persons having brown-eyed children.

Dark hair, such as pure Italians have, seems regularly to be dominant over the light hair as found in typical pure Scandinavians; and in the second filial generation from such crosses the proportion of recessives appearing light-haired is about one in four. As stated in Chapter XXI, the reason why dark hair is dominant over light hair is unknown, as is also the case with every other dominant trait. Probably some day we shall know the reason why, but at present not even a hint can be given.

Expressed diagrammatically we have:

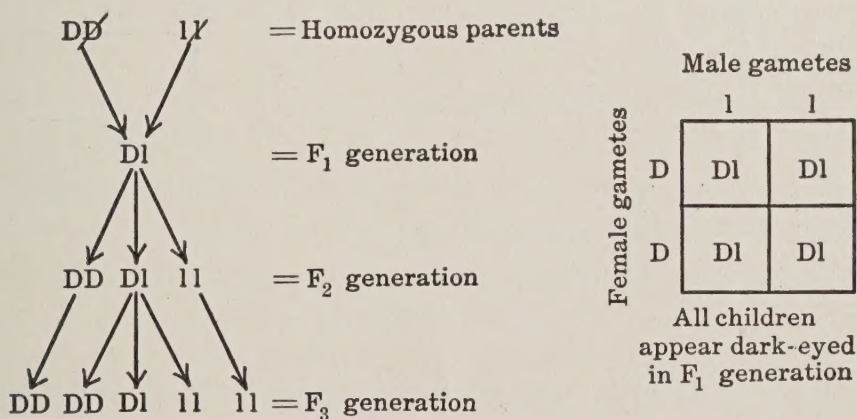


FIG. 101.—Lines through D and l of homozygous parents indicate maturation reduction.

¹ Some competent scientists hold to the theory of Nordic supremacy, others vigorously deny that there is any scientific basis for such a belief. Some hold that it makes a great deal of difference whether one is a blond or a brunette, while others deny it. Obviously the discussion is far from settled because of the lack of sufficient scientific data.

All the possible gametes for the male sex are D and D and the female d and d . Giving each male gamete an equal chance (two chances) to fertilize the female gametes, we have resulting only the zygote Dd , which among the heterozygous will always appear dark in the F_1 generation. If crossed, however, with another individual also Dd , the second filial generation would give on the average DD , Dd , and dd in the ratio of 1:2:1.

Curly hair has likewise been found to be dominant over straight hair, so if the individual possessing the curly hair is homozygous for this factor, and mates with a straight-haired individual, all the offspring will be curly-haired in the F_1 generation. All the possible male gametes are C and C and the female gametes s and s . The only possible zygote is Cs , which will always appear to be curly-haired, regardless of its heterozygous germ plasm.

Expressed diagrammatically we have:

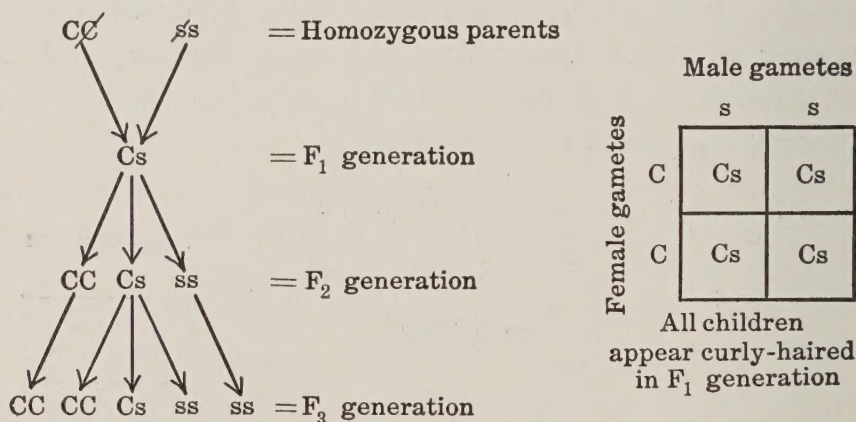


FIG. 102.—Lines through C and s of homozygous parents indicate maturation reduction.

In the second filial generation, if the heterozygote Cs mates with another Cs , there would result on the average a ratio of 1:2:1, three of which would appear to be curly-haired.

Facts regarding the inheritance of physical traits such as eye-color and hair-color are interesting to know and are of distinct value when dealing with certain important problems, such as racial or national origins, but the important thing about a race

is not these physical traits but rather its general level of mental capacity.

Although the studies carefully made on mental inheritance are comparatively meager, yet there seem to be several statements that can be safely made.

The study of feeble-mindedness has been particularly attractive to students of heredity. Feeble-mindedness is a large term including the range downward from those who are just barely below normal mentally to the very lowest. Three distinct classes of feeble-minded persons are commonly recognized—the *moron* (nearest normal), the *imbecile*, and the *idiot*.

Each of the three types is separated from the others by a rather arbitrary line, yet the typical examples of each are quite distinct. With the idiot and imbecile we shall not be concerned in this book because they are so hopeless and helpless (having to be cared for almost as infants) that they very seldom have offspring. No person with even a grain of sense would ever marry an idiot or imbecile, but that is not the case with the moron.

The moron, who is often of a quiet disposition, is frequently mistaken for a wise person, and a moronic girl or woman of beauty is often selected as a mate by a normal man. (It is interesting to note that almost any person can pass as wise if he will only be quiet and hold his tongue.) There are thousands of cases where normal men have selected moronic women for wives, but seldom do normal women approve of moronic men for husbands.

Now morons are not helpless by any means. With a large amount of practice they can learn to do almost any mechanical thing, but to improve upon the method used would hardly be possible for them. For example, a moron might learn through much repetition how to do one simple part of a complicated process in an automobile factory, or to do some one thing in a shoe factory, such as pegging on the heels, but in neither case could he design or improve upon any part of the automobile or the shoe. Morons have almost no originality or planning ability. They cannot adapt themselves readily to new conditions.

eration then we can have only type of zygote *Nf*, and all will appear normal since the feeble-minded trait is recessive.

On the whole it is a good thing that the normal mental condition is dominant over the feeble-minded condition, since all the children of the first generation of such a cross will themselves be as normal-minded as are homozygous normal people, even though they carry unexpressed the undesirable weakness. Likewise hundreds of thousands of people carry unknown to themselves and unexpressed in their offspring the feeble-minded trait as a recessive, since perchance on only one side of the ancestry for generations back has there been anybody either homozygously or heterozygously feeble-minded.

The undesirable possibility is that a couple who consider themselves absolutely normal as regards mental condition may have offspring who will be feeble-minded, if both carry the feeble-minded trait recessively. This is possible even though all of the living relatives on both sides are normal and also all those who are known for several generations back. Feeble-mindedness may be carried for many generations unknown, making its appearance only about once in four offspring if both parents are heterozygous for normal and feeble-minded mental traits.

It should be emphasized that a weakened mentality due to injury of the brain, such as might be caused by a severe fever or hard fall, is not inherited by the children. In that case the germ cells have not been affected, and all of the offspring resulting later will be as normal as if the fever or accident had never occurred.

It should also be emphasized that children or adults who are slow in learning are not necessarily feeble-minded. That there should be variation here as in all other traits it is only reasonable to expect. Slow learners are sometimes keen thinkers and may succeed as well in the end as those who easily grasp any situation. Nothing is so fatal as to inform such a child that he is stupid and therefore hopeless. At the same time, it is generally true that "good things go together." The quick learner is *more often* a keen thinker than is the slow learner.

Epilepsy is also considered to be a unit character and seems to be definitely inherited from one generation to another. Not so many cases have been available for study as of feeble-mindedness, but enough is known to make it fairly certain that a person subject to epileptic attacks is definitely defective in his germ-plasm. Epilepsy seems to be a recessive trait.

Insanity is also a topic that greatly concerns society. Unlike epilepsy and feeble-mindedness, it cannot be called a unit character, since there are numerous cases on record where normal children have been born from parents either insane at the time or who later became insane. In these cases the children were born normal and remained normal during adulthood. The reason often given to explain this apparent impossibility is that there are many kinds of insanity. That is, the mentally deranged condition known as insanity is brought about in a number of different ways. A diseased condition of the central nervous system, or the absence of a small part of the brain, or the failure of the development of certain glands, or many other causes, might result in insanity. If the parents were insane for different reasons, it is understandable that normal children might be born to them. On the contrary, if both parents were insane for the same inherited cause, then one would expect to find all the children insane. It is reasonable to suppose here as in other traits that, unless the parent expresses or carries recessively the insane factor, the children will all be normal.

Just as feeble-mindedness may be due to disease or to accident, so insanity is often brought about by external means, such as by shell-shock in war, by disease, or by excessive worry. Insanity produced in these ways is never transmitted to the offspring, even though the insanity might have been brought about before the fertilization of the egg that resulted in the offspring. Carelessness in differentiating between hereditary and acquired insanity has doubtless resulted in thousands of mistakes, quarrels, and embittered feelings.

Deafness and dumbness seem to follow certain definite laws, but at the same time appear to be irregular in expression. It is

believed by many that about the same rule holds here as in insanity—that unless both parents are abnormal from the same inherited cause the offspring need not be. It is obvious that deafness may be due to the absence of the ear-drum, the hammer, the anvil, or the internal organs of the ear. If one parent were deaf from one cause and the other from still another cause, it could be possible for part or all of the children to be normal, but not so if both parents were deaf from the same inherited cause. Dumbness, or the inability to speak, theoretically would follow similar laws, although this inheritance has not been carefully worked out.

The question is often asked whether genius is inherited, and if it is a part of the time, why is it not all the time. Enough data have not been collected to permit definite statements concerning the inheritance of genius. To make the matter still further complicated, a good definition of genius is not available, and much so-called genius is probably a product of careful training and much hard work.

Since the majority of the offspring of geniuses are not geniuses, one is led to believe that this trait either is recessive or is not a unit character at all. In other words, genius, if it followed the Mendelian law, could appear only about once in four children where the same trait of genius is carried recessively by both parents or where both parents are geniuses of the same type. Lacking this inheritance of genius, great achievement in any given field can sometimes be explained as the result of fortunate circumstances of birth and training, favorable opportunities, and (usually) much hard work.

Musical ability is often considered a “gift,” due to inherited musical talents. Since little conclusive evidence is available, only the conclusions of careful observers can be given and these often contradict each other. In a general way there seems to be such a thing as inherited musical ability or at least the ability to learn to play with little effort almost any musical instrument, and to play very complex selections. There are cases on record of children six or eight years of age playing musical com-

positions that adults are usually able to master only after long practice.

It is said that more than two hundred descendants of the original great musical genius, Bach, became very proficient in music. Now some of these descendants may have had a decided inherited talent for music; others may have followed the musical profession because of the desire to live up to the reputation of their distinguished ancestor and through effort developed, to a point that warranted recognition, what was natively perhaps only a moderate talent.

Such traits as mathematical ability and linguistic ability doubtless have an element of actual and particular inheritance in them to about the same degree that musical ability has. The important thing to keep in mind is that opportunity to develop the inherent genius must be presented or else this ability will continue to be dormant. Here again it is well to reemphasize that one of the important functions of the teacher is to give latent ability, whether average or remarkable, a chance to develop.

Another common question is whether criminals are "born" or whether they are "made" because of bad social conditions. Probably both hypotheses are true, the latter more frequently than the former. Even though there are so many opportunities for individuals to go wrong because of defective training in home, church, or school, there are undoubtedly some people, a very small percentage, who would go wrong under any conditions. This criminality may sometimes be due to faulty physical development, which could be corrected by the skilled physician or surgeon if discovered in time. Kleptomaniacs who sometimes are more than able to buy any of the things stolen are often quite unable to resist the impulse to steal. Likewise more serious crimes are sometimes committed by persons who assert with apparent sincerity that they "cannot help it." Whether this be true or not is a debatable question, but certainly there are many born with a strong predisposition to do those things which society labels as crimes.

For a detailed study of famous criminal families, one should study the data as submitted for the Jukes family and the Kallikak family. For an exactly opposite study one may select the family of Jonathan Edwards, where an exceptionally large number of descendants are found to have become very prominent for their good deeds. It should be kept in mind, however, that the data and conclusions of all three of these studies have been seriously criticized and in part discredited.

Longevity is also an interesting study for the geneticist. Here again very little is actually known, but the opinion of careful observers is worth consideration. S. J. Holmes has remarked that length of life is in his opinion probably more a matter of being born in a family with a long-life record than anything else. That great length of life seems to run in families is a matter of common observation. On the other hand there seems to be unquestioned evidence that by careful living one can increase the normal expectation of life for at least ten or fifteen years.

Often minor traits such as baldness, white patches in the hair, twitching eyes, peculiar marks on the skin, are cited as matters of definite inheritance, and doubtless they are, since three or four generations of a family may be observed displaying such traits. Just how and in what proportion the offspring should display these particular traits is unknown. Far too few careful tabulations are available to permit trustworthy generalizations.

At the present time a large amount of work is being done in collecting data on human inheritance, so that each year we may expect some of our questions to be answered.

The most important thing to remember about human inheritance on the physical side is that the same general Mendelian laws hold here as in the lower animals and the plants. That any person can inherit only one half of the traits of either parent may be disappointing news to many, particularly when it is understood that the half inherited from each parent is purely a matter of chance. The important truth to emphasize is that, in order to have healthy offspring, both parents of each parent should be of high quality; so that, regardless of what happens at

maturation and fertilization, the offspring, although different, will be of high quality.

Although each person inherits one half of his traits from each parent, yet only half of the total traits inherited are expressed, while the other half are carried latent. As a general rule, due to the law of chance, one half of the traits expressed will be from the maternal side and one half from the paternal side, although it is theoretically possible that, once in a long while, all of the expressed traits may be from one side. In such a case all of the latent or carried traits will be those of the opposite parent and some of these may re-appear in later generations.

Although pure homozygous breeds of plants and animals are usually much "better" than the mongrel heterozygous ones, yet this does not necessarily hold good for the human species. In the plant and animal realm, pure breeds are desired because of their increased economic value as breeders of their kind and because they may be more productive. Since the human being is not brought into the world because of his money value and since a standardized human being is not desired, it is obvious that the offspring of crosses between healthy individuals of different nationalities may be as desirable as those from parents of the same nationality.

The important thing in human inheritance is not that the individuals shall be homozygous on outstanding and noticeable traits, but that they have healthy bodies and a potentially healthy mental condition. With this type of inheritance, even though greatly varied in external appearance, the chances are that one can live a happy and successful life.

QUESTIONS

1. Why is it more scientific to speak of human stocks than of human races?
2. What reasons can you assign for the fact that the Scandinavian peoples are of relatively pure stock?
3. Why is it important to have homozygous domesticated animals?
4. Why is it relatively unimportant to have homozygous human beings?
5. Name a nationality or a people that has apparently been benefited by a mixture of widely heterozygous stocks.

6. Name a nationality or a people that has been injured by a mixture of widely heterozygous stocks.

7. Which do you think would be better: (1) to strive to produce a race of geniuses, or (2) a race of healthy people with a normal distribution of intelligence?

8. Do you think such facts as brought out in this chapter should be taught in the elementary grades? The junior high school? The senior high school?

9. Make a summary of the important ways in which one's attitude toward education might be modified by a knowledge of the facts brought out in this chapter.

CHAPTER XXIII

THE IMPROVEMENT OF THE HUMAN SPECIES

Eugenics versus euthenics—Reasonable requirements and expectations for the near future.

It is only natural that the practical man as well as the idealist should ask, "What can all this knowledge of heredity do to improve the human race? "

Immediately one has to face two problems—namely, What can be done now in the next few generations, and, what is possible in the remote future? Since, with our present limited knowledge and vision, no one knows what may or may not happen in the remote future, consideration will here be given more especially to reasonable expectations for the near future. Theoretically almost anything can happen in the remote future.

Again, even this part of the problem of human improvement must, for discussion, be divided into two parts: What could be done to improve the race in two or three generations if everybody knew enough, cared enough, and were willing to help in the experiment, and, what is a reasonable prospect, considering the present ignorance of the people and their present attitude of indifference toward the improvement of the race?

Before one attempts to formulate reasonable and possible ways for race improvement, it is obvious that one must set forth the need for improvement. Does the species need to be improved, physically and mentally? Improvement morally and spiritually will not be discussed here, first because the exact kind of moral and spiritual improvement to be desired could not possibly be agreed upon, even by the leaders of thought in the social sciences, and secondly because, with healthy bodies and potentially healthy minds, moral and spiritual progress will probably follow.

Let us first discuss the question of whether the human race is in need of physical improvement. Perhaps the best way to answer this question is to ask another: Can one name any other species of animal or plant life that is in such poor physical condition? Does any other species have so large a percentage of sick, weak, crippled, and otherwise physically helpless members? To both of these questions it seems that the answer must be, *No*. In species out in the wild, the sick, weak, and crippled are quickly eliminated by the process of natural selection and thus seldom have offspring to continue the weak or abnormal traits of the parent.

We often see weak human beings (not including elderly people), but how often does one see weak crows, rabbits, wolves, English sparrows, or jays, out in the wild? If they are below standard, they soon become the food of some other species or are otherwise crowded out of the race. In domesticated species, man arbitrarily eliminates the unfit, especially as breeders for the next generation. Only in mankind are the weak allowed to live and reproduce generation after generation; it seems reasonable to believe that this tends to increase the number of abnormal individuals.

The second question, whether the human race is in need of mental improvement, can also be best answered by asking another question: Can one name any other species that has so large a proportion of weak-minded individuals corresponding in our species to idiots, imbeciles, and morons? The answer, *No*, is easily given and easily substantiated by observation. An individual out in the wild that is much below the average in instinct, wit, and adaptability is soon cut off and almost never has offspring. By this harsh method nature preserves only the better individuals.

It is a fact well known to every student of heredity that in most civilized countries, the less well circumstanced classes of society are reproducing faster than the more intelligent and in general the better circumstanced classes. Part of this lower birth rate on the part of the more intelligent is doubtless self-

imposed, selfish in the main; on the other hand the lower classes usually have numerous offspring just because they can know no better, or do not care.

It should be particularly emphasized here that an uneducated person does not necessarily carry weak germ plasm. This is particularly true of immigrants from other countries who have not had a chance in their native lands. Often these ignorant peasants have a superior germ plasm which will become evident in the next generation in this land of opportunity and of free education. Nor does weakness, sickness, or a crippled condition due to accident imply undesirable germ plasm.

How can the chances of the next generation be improved? A few perhaps would wish to imitate nature by killing off those individuals who do not come up to a certain standard. Even if we disregard the inhumanity of this proposal, however, its impracticability is obvious. Who is to be the judge of who should be killed off? Who will set up the standard? Who will do the killing? How will it be done? This cure is clearly impossible. It would leave the survivors brutal and hardened. It would mean the sacrifice of some of the finest products of social evolution.

Another method which is indorsed by many students of the problem is that individuals below a certain standard should be prevented by a relatively simple and safe operation from the possibility of propagating their kind. While this involves no cruelty, there are vigorous objectors to the proposal.

Although the operation is comparatively simple, the very fact that an operation is performed, thus depriving a person of certain parts or functions of his own body, is looked upon by many as unjustifiable personal interference. There is little doubt, however, that this method should be adopted for the very worst cases among the criminal classes.

The third possibility of ridding the world of defectives of all kinds is that of segregating the sexes in institutions. This method, of course, is a much slower process and much more expensive—one hardly feasible where a country is extremely

crowded or poor. Such, of course, is not the condition of the United States. One great advantage in this procedure is that it could call forth little protest from the ultra-sympathetic and the extremely sentimental. True, they might contend that even here personal freedom is interfered with, but it should not be difficult to explain that this is but little to endure when compared to a life-long handicap on the part of the next generation born of weak, diseased, or criminal parents.

The inmates of these institutions should be treated very kindly, well fed, comfortably clothed, and otherwise treated as human beings. The important thing is that the isolation should occur early, before they are capable of transmitting their weaknesses to a following generation. Of course, if all such undesirables should be so segregated, there would be great crowding for about a quarter of a century, then a gradual diminishing of numbers until only those accidentally born abnormal from apparently normal parents, would be present. It should be kept in mind that abnormality will probably re-appear in every generation among offspring of normal people carrying recessive traits, but such cases would be comparatively rare.

As one famous American sociologist said, it is a sign of "mollasses headedness" that we allow the most unfit and the highly undesirable to become the parents of the next generation.

There are in each generation some people who refuse to marry because of known weaknesses in the family, which they are unwilling to risk handing down to innocent children. This action is certainly to be commended as a fine consideration for the welfare of the race. However, it is not to be hoped that any large percentage will be so idealistic, since handicapped persons are often unable to think in terms of the next generation or are unwilling to make any sacrifice for it. Viewed in this light it is unfortunate that the sex instinct is more deeply ingrained than any other, save possibly the instincts for food-getting and self-protection. Were it not for this fact, the problem would be less complicated.

A number of states already have laws for dealing with the un-

fit, particularly of the criminal classes. Different states have different laws, some very drastic, such as de-sexing the criminal offender. There is much trouble in enforcing such state laws, however, since too few people are sufficiently alive to the grave danger to the race involved; thus the law becomes too often a dead letter. It is true in this field, as in many others, that greater success has been achieved in discovering new facts and laws of heredity than in the making of these facts and laws understood by the average man. In a democracy, education must always precede legislation if willing obedience to law is to be expected.

In addition to the isolation of the weak-minded, the diseased, and the criminal, there are a few other practical measures that could be enacted into laws and enforced immediately with wholesome results to the population in general.

The first is already in effect to a certain extent—that of barring from immigration to this country the diseased, the criminal offender, and the otherwise unfit. Such a quarantine started a number of years ago by our government has been fairly effective so far as the landing of unfit immigrants at our main seaports is concerned, but not nearly so effective in keeping undesirables from crossing our northern and southern borders, particularly the latter.

Another practical procedure would be to have uniform marriage laws for all of the forty-eight states instead of the lack of uniformity that now prevails. If two people wholly unfit who desire to marry and thus pass on their undesirable traits to the next generation cannot secure a license in one state the cost of two railroad fares will often enable them to do so in another state. Thus it is safe to say that no individual in the United States is denied the privilege of marriage, including those with loathsome diseases, the weak-minded, and the worst criminal offenders.

Still another practical procedure, wholly within the possibility of enforcement, is to require rigid examinations, physical and mental, of all individuals before the issuance of a marriage license. The standard should be set rather high and the examina-

tion should be made by physicians appointed for such a purpose by the city, county, or state authorities.

If these four methods of procedure could be carried out in every part of our land—namely: (1) segregation of our present undesirables in institutions; (2) restriction of immigration of undesirables to this country along all the borders, as well as at seaports; (3) uniform marriage laws in all of the states; and (4) examination before the granting of the marriage license—very noticeable improvement could be made even in one generation.

If these four measures were carefully carried out for one generation, it is altogether probable that succeeding generations would make stricter and stricter laws as the benefit of those in force became evident. After all, it must be expected that the enforcement of laws for the improvement of the race will be a slow process, as has been the case with all other fundamental improvements. It is for the idealist to point to a goal of near perfection to be obtained in the remote future; but it is probably even more important that the practical man have another goal whose attainment is possible in his own generation. The above four measures are entirely practicable means toward the eugenic improvement of the race, and in the writer's opinion no one of them could be safely omitted.

Even though those informed must content themselves with gradual improvement, there is nothing more alarming than the fact that the unfit are reproducing more rapidly than the fit, in proportion to their numbers, and nothing is more fundamental to the survival of the race than the reversal of this tendency. A people with healthy germ plasm will seek out or make for itself a fine environment.

Improvement of the germ plasm of the race is known as *eugenics*. Improvement of the race by means of an improved environment is called *euthenics*.

The question is often asked which is the better way to improve the human species: by the science of eugenics, or by that of euthenics. The question is obviously equivalent to the much older one—Which is more important, heredity or environment?

In a sense either question is very foolish, particularly the latter, since life is possible only when both factors are present. We all agree, however, that there are different degrees of favorable environments and different degrees of quality in inheritance.

Perhaps the best way to settle the question of the relative importance of eugenics or euthenics is to observe what has happened in the past. With very rare exceptions, the many reformers of the various countries of the world since written history began have tried to improve the race or nation by improving the living conditions of the general populace—by euthenics. The results obtained in almost every case have been decidedly worth while, in terms of comfort and happiness for the general public, but with the passing of the reformer the populace settled back into its former unhygienic and slothful ways. Such improvement is always temporary and is doubtless brought about by the better germ plasm of the race, nation, or community forcing its program upon the rest.

For six thousand years race improvement has been attempted by the euthenic process alone with too few permanent results—in fact with almost no noticeable improvement to the germ plasm. It seems reasonable, therefore, to assume that this is not the right way to begin to improve a race, but rather is merely the essential accompaniment.

With considerable scientific basis for their belief, the eugenists hold that race improvement will never take place until the weak germ plasm diminishes and the better germ plasm is found in a greater proportion of individuals. In just the degree that this takes place will the race become better, the eugenist maintains. But even the most ardent eugenist would not deny that a fine environment, such as comfortable homes, good schools, wholesome food, good pictures, good music, will help the individual to live a finer and more abundant life. At the same time, it must be remembered that only those with the better germ plasm really desire such things and bring such things to pass.

Stated in another way, good environment alone will never develop better germ plasm, but better germ plasm will quite nat-

urally lead to the development of an increasingly better environment. *The most fundamental thing in life is to be born with fine germ plasm; this can take place only if the parents and grandparents possess such germ plasm.*

The teacher's part in bringing about the improvement of the species can be but indirect. Obviously the teacher cannot change the inheritance fund of the children now in the classroom. His chief duty is to supply the best possible teaching, which is an environmental influence, in order to develop the latent traits in the children. However, by spreading the known facts of heredity wisely to those qualified to understand, the teacher can indirectly aid in the improvement of the next generation.

Race improvement is a problem not to be solved by reformers rapidly and completely in one generation, but gradually in the light of scientific discovery over a long period of time covering perhaps many generations; but its gradual solution is vital to the persistence of the race.

QUESTIONS

1. Why has eugenics alone failed to produce a high type of civilization where most of the individuals are physically and mentally fit?
2. Why is eugenics alone not likely to produce a high type of civilization?
3. Why is it difficult to get people to apply eugenic principles to marriage problems?
4. Should love for the other person be the only consideration when contemplating marriage?
5. If not, what other facts should be included?
6. If we had uniform and good marriage laws, in all of our states, could we avoid entirely the birth of deformed, weak, and feeble-minded children? Why or why not?
7. In what ways can the average classroom teacher help in bringing about the birth of better children in the next generation?
8. If any of the facts brought out in this chapter could be taught in schools below college grade, state which facts should be taught and why, and where they might best be introduced.

CHAPTER XXIV

INHERITANCE OF ACQUIRED CHARACTERS

Lamarck's ideas—Weismann's contributions—Recent experiments on the inheritance of acquired characters—The present status concerning the inheritance of acquired characters—The teacher's attitude toward the question of the inheritance of acquired characters.

From the point of view of educational theory, one of the most important topics in the field of biological science is that which has to do with the possibilities of passing on through the germ cells the changes that are made in the organism during individual life, the changes that experience brings about.

The ancients of all nations believed that traits and characters acquired by the parents were transmitted to the offspring through the germ plasm. Scientists living in the Middle Ages held this view, as did the scientists of modern times up to the time of August Weismann (born 1834). The "inheritance of acquired characteristics" was not until recently, therefore, an important subject for discussion in scientific circles, because all scientists took such an inheritance for granted. It seemed both obvious and reasonable. If the question were ever seriously raised, one would probably have dismissed it with the reflection: "What is the use of living a decent life or of doing anything worth while if there is no such thing as the inheritance of acquired characters by our offspring?" This is not the empty expression of unthinking persons, for many famous men, including Herbert Spencer, were unable to understand how improvement and evolution could take place unless acquired characters were transmitted to the succeeding generation.

To the majority of present-day scientists it seems strange that no one seriously questioned this universal assumption until August Weismann raised his voice in the latter half of the nine-

teenth century. So successful was Weismann in supporting the contention of the non-inheritance of acquired characters that not only has the opposition long since been put on the defensive

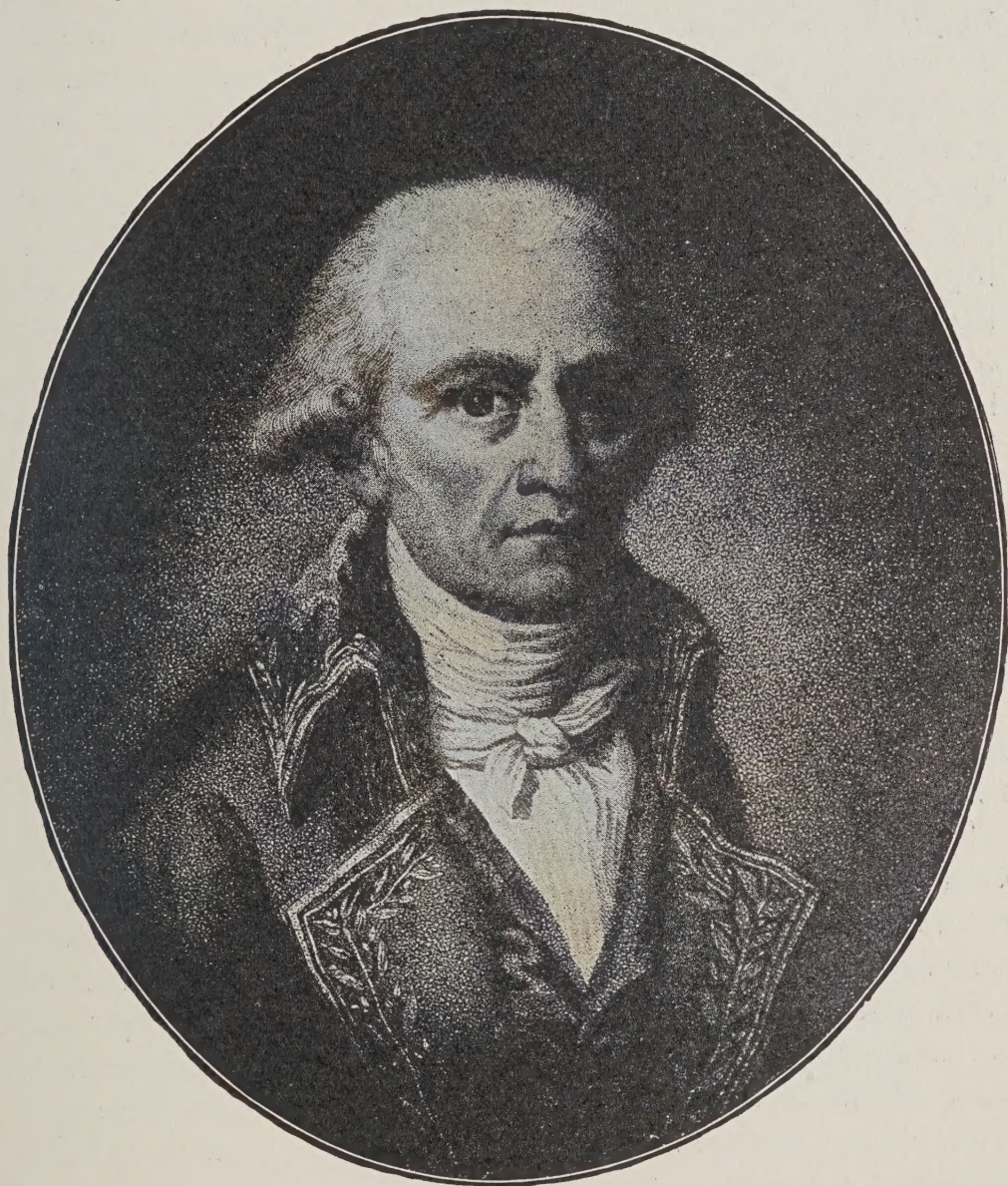


FIG. 104.—Lamarck, 1744–1829. (From Loey, *Biology and Its Makers*, by permission of the publishers, Henry Holt and Company.)

but a biologist who would to-day proclaim the possibility of such inheritance would have to produce the most convincing evidence in order to secure a hearing.

Since Weismann led the attack on this theory, he is usually cited as the chief representative of the Weismannian school, and his present-day followers are called neo-Weismannians. The few who uphold the theory of the inheritance of acquired characters are often called Lamarckians or neo-Lamarckians, since Lamarck, a French zoölogist, was the first prominent scientist to set forth a substantial theory of evolution based upon the inheritance of characteristics acquired during the lifetime of the individual.¹

In fairness to the neo-Larmackians it should be stated that they believe that acquired characters *may be* transmitted, not that they always and necessarily *are* transmitted. It is also equally fair to state that the neo-Weismannians do not question the inheritance of acquired characters in one-celled life such as the protozoa and bacteria where the germ cell and the somatic cell are one and the same thing; it is only where there are distinct somatic and germ cells present in the same body, and particularly where there are two sexes in different individuals (commonly known as the dioecious type) that they deny the possibility of such inheritance.

Let us examine the main arguments advanced by the Lamarckians and Weismannians, who respectively uphold and deny the possibility of the inheritance of acquired characters.

The central hypothesis of the Lamarckians is that new traits or characters are produced in response to a continued demand over long periods of time for such a trait or characteristic; and, conversely, that traits or characteristics no longer needed or but little used gradually ceased to exist. Often the phrase, "use and disuse" or "use-inheritance," is employed to cover the situation. Even though this terminology is somewhat inaccurate, we shall employ it, since it is and doubtless will continue to be used by the majority of biologists.

With the idea of "use-inheritance" as the fundamental assumption, the Lamarckians were able to offer a theoretical ex-

¹ Although Lamarck and Weismann are usually considered the leaders of the two sides, it should not be inferred that they were contemporaries, since Lamarck died in 1829, five years before Weismann was born.

planation for change and adaptation taking place in species—in other words, for evolution. They further assumed that each species continually attempts to adapt itself to its environment and its associates, and that in the process of adaptation the

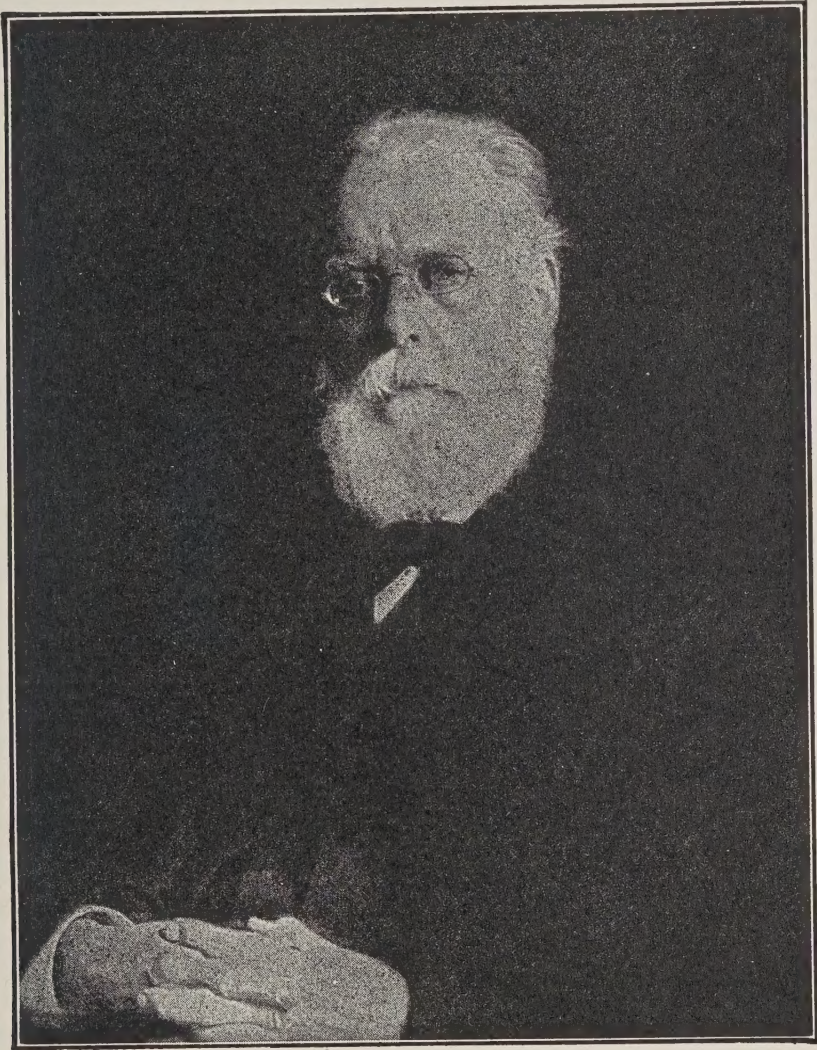


FIG. 105.—August Weismann, 1834–1914. (From Locy.)

germ plasm is necessarily changed, with the possibility of the next generation's inheriting these specific changes in adaptation. According to this view, the long-continued accumulation of changes in any species would, eventually, develop new species or at least new varieties.

Probably the most substantial argument of this school is that species do change to meet their environment and that they do adapt themselves to their surroundings. This is evident on the face of things. Now, unless one thinks carefully on the subject, one is inclined to let such an argument stand, but those who negate the Lamarckian theory can show, paleontologically speaking, that, compared with the species that have been successful in adapting themselves to the environment, several times as many species have failed to change in order to meet their environment effectively and so have gone out of existence. Those who oppose the Lamarckian theory maintain that individuals are able to live in a given area not primarily because of the adaptation of the individual to the environment but rather because the environment sorts out and selects the favorable chance variations which are already adapted to it.

The most significant weakness of the Lamarckian theory, however, is involved in one of its fundamental assumptions. If acquired characteristics are transmitted through the germ plasm, the Lamarckians must necessarily assume that there is a direct and easy connection between the germ and somatic cells, so that the changes in the latter can in some way impress themselves upon the former. The Weismannians point out that just the opposite is true. They emphasize the great probability that the germ cells are thoroughly insulated from the body or somatic cells and that changes in the body or somatic cells in one generation cannot be carried over into the next generation by way of the germ plasm.

The Weismannians, then, use as their main argument (1) that there is no known process or mechanism by which the acquired traits of any bodily organ can be transferred to the germ cells, and (2) that the Lamarckians can show no case where there has been unquestioned transmission of acquired characters. They go on to say that there is much evidence to the contrary, as for example, the fact that lambs are born with long tails, even though lambs' tails have been cut off consistently for thousands of years, and that Chinese girl babies are not born with deformed

feet even though it has been the custom for centuries to bind the feet of the women. Weismann experimented for nineteen generations by cutting off the tails of rats only to find that the tails of the adults of the nineteenth generation were not shorter but were actually a little longer than those of the first generation,—doubtless due to better food or some uncontrolled factor.

It is also well known that accidental mutilation of the parents' fingers, toes, arms or legs, has no effect on the normality of the children of the next generation. In other words, mutilations, accidental or designed, are now generally agreed upon by both sides as in no way affecting the offspring. It is only fair to state also that most of those who uphold the Lamarckian view do not deny that in 99 per cent of the cases, acquired traits are not transmitted to the next generation; they contend, however, that if the phenomenon occurs even a fraction of one per cent of the time, it is sufficient evidence to substantiate their contention and to establish it as the most important factor in the evolution of species.

In the entire discussion of the inheritance of acquired characters, care should be taken to differentiate between *actual* and *congenital* inheritance. The actual inheritance comprises only that which is inherent in the germ plasm, transmitted by means of the chromosomes to the next generation regardless of the health of the animal and regardless of all external conditions, such as climate. The actual inheritance of the next generation is complete upon the fertilization of the egg by the sperm cell. Congenital inheritance, on the other hand, includes the factors which may be experienced by or added to the embryo after fertilization and before hatching or birth. For example, whatever happens to the unhatched chick during the three weeks' incubation period, or to the babe during the nine months before birth, is congenital and not actual inheritance. A specific example is that of the child born with the measles because the mother was afflicted with that disease or with syphilis because the mother was also infected.

The moment that the male gamete unites with the female

gamete to form the zygote, which will develop into the babe, the inheritance of that individual is complete. In other words, the "gate of gifts" is closed at fertilization, not at birth, as most people have believed. The mother is therefore more important to the unborn child than is the father, since she contributes one-half of the inheritance fund and all the environment of the unborn babe for the first nine months. The nine months' gestation period of the human embryo, then, is the time when "congenital" inheritance may be forced upon and added to the "actual" inheritance of the embryo.

It is largely because of the failure to distinguish between congenital and actual inheritance that our literature on the subject is so confusing. Over and over again congenital inheritance has been treated as if it were actual inheritance, and thus numerous wrong conclusions have been drawn.

It is also true that it is sometimes hard to differentiate between that which has been acquired in some way before birth and that which was transmitted through the chromosomes. For this reason, many supposed examples of acquired characters are but the recurrence of inherited characters. Furthermore, it is often difficult to be sure that a trait is really acquired and not a latent or a slow-appearing one. Great care must be used in selecting undebatable cases when drawing conclusions concerning this subject.

The argument sometimes used by Lamarckians that a new species is not possible unless acquired traits can be passed on to their offspring, can be easily met by their opponents. The Weismannians hold that there is ample chance for the formation of new varieties and even new species, following the common Mendelian laws, as exhibited in dihybrid crosses, or the accidental doubling of chromosomes as in some kinds of common wheat, or by the accidental loss of a chromosome. Theoretically, each side can show how new species may be formed and therefore how evolution might be possible.

Theory aside, what is the actual evidence in favor of each contention?

Among the chief workers in the field of the inheritance of acquired characters are Kammerer, Guyer, Stockard, Pearl, Bilski, Whitney, Noyes, Frinesinger, Bluhm, Correns, and MacDowell. Of course there are hundreds of others engaged upon this subject. H. S. Jennings, writing on "The Inheritance of Acquired Characters" in the November, 1926, issue of *The Forum*, makes this statement: "The outstanding support for the inheritance of acquired characters is the work of Kammerer, who believes that his fourteen years' continuous research, mainly on the amphibia, demonstrates that environmental effects are indeed inherited."

Many scientists, influenced mainly by Kammerer's work, felt that they might have to change their views and admit that some acquired characters may be transmitted. Then came the startling announcement in October, 1926, that Kammerer had committed suicide because of his discovery that some one or several of his friends or coworkers in his laboratory had been artificially coloring his frogs, in order that he might not be disappointed in his attempt to prove the existence of such transmission!

Kammerer, on finding out what had happened, immediately admitted that someone had been interfering in his experimentation, and being unwilling to meet what he thought would be the criticism of his fellow biologists throughout the world, he foolishly chose to end his life. No one at this writing seems to question the absolute sincerity and honesty of Kammerer; on the contrary, his sincerity and his scholarly attainments made him many friends and admirers.

Although all of Kammerer's work of fourteen years on amphibia must now be doubted, yet according to Jennings there remains his work on sea-squirts which has been attested by other investigators. Kammerer repeatedly amputated the siphon in sea-squirts and found that the resultant stimulation produced much longer siphons and that the offspring of these individuals in turn produced, without stimulation by amputation, siphons of unusual length.

Professor Guyer's work shows that the introduction of foreign serums into the blood of rabbits in some cases produces inherited eye defects, but others who have repeated the experiment have not been able to get such results. Because of this fact, many believe that Guyer must have been working with rabbits that carried these eye defects. However, no one who knows Guyer doubts that he obtained just the results that he published.

Practically every experiment thus far carried on that tended to show that acquired characters are transmitted, has met with some similar fate, so that many biologists have come to doubt any such conclusion. T. H. Morgan has asserted that "belief in this doctrine [of the inheritance of acquired characters] is based not upon scientific evidence, but upon desire to pass one's acquisitions to one's children." Because of this desire, doubtless there always will be a new crop of scientists attempting to prove the validity of Lamarck's theories. However, at present we shall have to admit that the Lamarckian hypothesis has little but hope and belief to substantiate it.

Those who uphold the theory of the non-inheritance of acquired characters are legion, due principally to the fact that the Lamarckians have been unable to produce evidence for the support of their theories. In other words, the strongest evidence for Weismannism is the failure of evidence for Lamarckism. Even in case of the most severe adversity or injury the offspring, so far as our present knowledge goes, does not inherit altered chromosomes. To be sure, there are hundreds of cases of the alteration of characteristics of a species by changes in the environment. No conclusion of the geneticist is more certain than this, *but that the actual inheritance fund, the chromosomes, are altered and pass this particular alteration on to the next generation, is very questionable.*

To the upholder of Weismann's views the evidence is overwhelming that these changes are brought about simply by the re-arrangement of the genes in the processes of maturation and fertilization. Nature is continually producing in most species a large variety of individuals, from the weak and unfit to the finest

and strongest. Since all of them can hardly be equally well adapted to any given environment, some of them fail because of competition, and as a consequence those with a fortunate combination of genes in the successful individuals live and populate the area. In other words, selective elimination of the unfit germ plasm is going on all the time, thus allowing for change and evolution. No additional method is necessary to accomplish and to explain adaptation to the environment, so the Weismannians claim.

Some have said that Weismannism is Darwin's theory of the survival of the fittest carried over into the field of the germ plasm. In a measure, that is true, but the analogy is not complete. Weismannism practically assumes that the genes have always existed, whereas Lamarckism assumes that in some way totally new genes are produced upon demand or lost for lack of use.

Laying aside for the moment the question of whether once in a long time an acquired character may be transmitted to the offspring, we find both sides agreeing, as stated previously, in the fact that in ninety-nine per cent of the cases no such transfer exists. After all, is it not probably a good thing that such is the case, when one thinks in terms of the whole human race rather than in terms of one's self and one's immediate relatives and friends? Think of the unfortunate behavior, functions, and structures that would be inherited! That the child is insulated to such a large degree, if not completely, from the rash habits and the unfortunate experiences of his progenitors is not at all a disadvantage.

Of course the other side of the picture is not so pleasing, because one likes to think that one can make one's offspring better biologically by doing certain worthy things. But perhaps it is better that our children attain for themselves certain ends or heights, than that they be born with these ends attained. It is true that the son sometimes becomes the great mathematician that his father was, and this may be because he inherited about the same chromosomes that his father inherited, and that he was

placed in a good environment for the development of these latent traits. This is much more reasonable to believe than that the mathematical efforts of the father improved the germ plasm in a mathematical direction!

The inheritance of disease is naturally a very interesting topic, both to those who affirm and to those who deny such transmission. At present, there seems to be no evidence that any disease has ever been actually inherited. The difficulty with those who maintain that such inheritance does take place is that they do not differentiate between "congenital" inheritance, early infection in childhood or infancy, and actual inheritance.

Perhaps the best example of congenital "inheritance" is that of syphilis. That children are born with syphilitic germs in their bodies, often widely distributed, there can be no question, but on investigation it is found that the mother also has or has had the disease and that the child has been infected during the foetal period. The syphilitic germ is decidedly motile, capable of penetrating nearly every organ of the body of the mother; it may easily penetrate into the tissues of the unborn child so that the child harbors the disease before birth.¹ In no way has the chromosome make-up been changed, and if the child's body can be completely rid of these germs before reaching adulthood and marriage, as now seems possible though at some risk to life, the next generation will not be born syphilitic. Although syphilis is not actually inherited, yet from the standpoint of the individual it is often about as serious as if really transmitted through the chromosomes, unless complete cure is effected. It is still a risk to marry a person who has ever been infected with syphilis.

Perhaps the best example of failure to differentiate between infection with a disease in early childhood and real inheritance is in the case of tuberculosis. Often a child is born in a home

¹ There is an obvious reason why the germ of syphilis, *Treponema pallida*, cannot be transmitted in the chromosomes of the human being, which are known to carry the inheritance fund. The syphilitic germ cannot enter the chromosome for the same reason that a sheep cannot enter a rat. The relative sizes of germ and of the chromosome preclude any such possibility.

where one or both parents have tuberculosis; subsequently, the child may contract the disease, and those not aware of what actual inheritance means will state that it is a case of the transmission of acquired characters. As a matter of fact, children born in such homes are likely to be infected with tuberculosis germs very early and perhaps often, and unless, for some reason, they are able to resist the germs, they will then or later become tuberculous. Children born of tuberculous parents but separated from them do not develop the disease. Calves born from tuberculous cows are likewise free from the disease if segregated.

It is thought by some that a child may not "inherit" tuberculosis even congenitally, since the disease germ is non-motile and therefore not able to penetrate the various tissues of the body.

It is now believed by biologists that no bacterial or protozoan disease of any kind is actually inherited by the human being; this, if true, is very fortunate.¹ The importance of a wholesome environment and freedom from contact with disease germs thus becomes evident. Environment does not become less important to one who knows the facts of heredity, but more important. The better the environment, the more numerous the chances that a good inheritance will have to develop good traits, and the fewer will be the chances that a poor inheritance will develop bad traits. Here is the opportunity of education both in the home and in the school.

One should not overlook the fact that offspring born of diseased and weak parents, especially if the mother be weak or diseased, are likely to be weak because of lack of sufficient nourishment of the right kind during the embryonic development. Children born of such mothers are often very susceptible and are likely to contract the first disease with which they come in contact. More often than otherwise the disease contracted will be one with which one of the parents or a brother or sister is afflicted because the chances of contagion are greater in such

¹ See Chapter XXII for details.

cases. The limitation of food supply or the feeding of the wrong kind of food is one of the ways in which the young child's development can be arrested.

It is safe to conclude that, if the transmission of acquired characters does take place through the germ cell, it is so rare an occurrence that no reliance can be placed upon this method for the improvement of the next few generations of human beings. So far as education is concerned, the mastery of mathematics, science, history, and the like can be achieved only through the individual's own efforts during each succeeding generation. It therefore behooves all teachers to make as favorable an environment as possible for the children in their care, in order that the traits which lie dormant may be allowed to come to the fullest possible expression, and *in order that desirable traits which cannot be passed on through the germ plasm may be passed on through instruction, discipline, example, and inspiration*—such traits, for example, as literacy, good manners, moral standards, and good health habits, as well as the knowledge that the race has accumulated and refined during the long ages that have elapsed since man first became man. In an important sense, the fact that acquisitions cannot be passed on through physical heredity gives to social heredity (of which education is the chief agency) its great opportunity and its great responsibility.

QUESTIONS

1. Why do you think nearly everyone prior to Weismann's time believed in the inheritance of acquired characters?
2. What do you think might have lead Weismann to question the doctrine of the inheritance of acquired characters?
3. Does it seem to you a desirable thing that the germ plasm is so thoroughly insulated from the body and its experiences? Why?
4. How might a belief in the inheritance of all acquired characters become a disadvantage to a future physician?
5. How can we be sure that a trait of any human being is an acquired trait and not a latent or a recessive trait?
6. Why cannot this question of the inheritance or non-inheritance of acquired characters be completely settled in every detail beyond the possibility of a doubt?

7. Which side of this question do you take? Why?

8. What important responsibilities does the non-inheritance of acquired characters place upon education?

9. In your judgment, would it be advisable for everyone to know the more important facts brought out in this chapter? If so, where, in your judgment, should these facts be taught?

CHAPTER XXV

CIVIC BIOLOGY

Important contributions of biology to civic welfare—Bacteriology and the control of disease—Biology as a main factor in the lengthening of human life—Hookworm, malaria, yellow fever, trichina, Texas fever, house fly, mosquito, and other pests conquered or controlled as the result of biological investigation—The important part played by biology in the digging of the Panama Canal—The æsthetic side of biology.

It is only natural that the man with a practical turn of mind should ask, "What has the science of biology contributed to the actual improvement of human welfare? How has biology helped to enrich life?"

Probably no science has added more to the actual well-being of the human species than has biology in its various divisions and applications. This has been particularly notable in the progress that has been made toward better health, more and better food, more and better clothing, better homes, and more useful and beautiful animals and plants.

Progress in the science of agriculture, the most fundamental of all human occupations, has been due largely to the advancement in three great sciences—namely, biology, physics, and chemistry. Formerly farmers were often unaware that the phenomena studied by these sciences form the basis of nearly all agricultural activity; but this is certainly not true of the present generation. There would be little left in the curricula of the agricultural colleges if the courses in these three sciences were removed. In some ways biology plays the largest rôle of the three in scientific agriculture, since obviously a farm or ranch of any kind is first of all dealing very directly and definitely with living things.

In scientific plant and animal breeding, which is practical

genetics or the applied science of heredity, enormous strides have been made, particularly during the past twenty-five years. Prior to that time improvement in any given plant or animal species was largely a matter of "trial and error" with error winning most of the time. Trustworthy results could be obtained from experiments only when a large number of individuals of a species were available for experimentation. From these large numbers a few favorable individuals were likely to appear. If these happened to be homozygous for the trait desired, the breeder could make definite strides ahead; if they were heterozygous in the second filial generation, he was often to be completely baffled.

Since 1900, however, it often has been possible to make short cuts in breeding and to secure in a few generations results that formerly required many generations. Indeed, results in the improvement of a species are now obtainable through science that otherwise would have been impossible. It is estimated that at least two hundred new varieties of plants and animals are produced every year, largely by relatively accurate and dependable scientific methods. Most of these new types are doubtless of little use and may not even represent improvement, but a few usually prove to be of inestimable value. It is largely due to the applied science of biology that we now have more and better food from the same number of animals previously used in breeding. We also have more and better wool, cotton, silk, and linen from the same acreage of cultivation. This is accomplished even without increasing the number of individual animals or plants.

The method of propagating trees through grafting and budding has long been known to the agriculturist, but the biologist has explained these processes and thus led to their improvement. The great care now taken of fine old trees by tree surgeons is further evidence of the advance made in this branch of biological science. With the cost of lumber steadily mounting, it becomes increasingly necessary that forest resources be carefully conserved. The knowledge that the biologist has discovered regard-

ing the growth and reproduction of trees and regarding the life cycles of insect pests and of vegetable parasites has been important here. Many new beautiful and fragrant flowers have been produced by plant breeders through the application of biological principles.

In the field of landscape architecture and gardening the importance of biological knowledge is again evident. A landscape architect must have a thorough training in botany and zoölogy.

Although the greatest practical achievements of the biological sciences have probably been in the field of producing more and better food and clothing from the same number of individuals, or from the same area, and although biology has contributed much to the improvement of the home and of the art of living, yet the contribution of greatest human value has undoubtedly been in the promotion of better health—the prevention and cure of disease.

Largely because of the activities of biologists, it is now known how to prevent and cure the hookworm disease so prevalent in many warm countries. The presence or retention of tapeworms in the intestines is no longer necessary, if the preventives made available by biological research are used. Malaria and yellow fever are rapidly vanishing from the earth because biologists worked out the life cycle of the mosquito and traced the development of the malaria germ in the blood of man and in the mosquito's body. Incidentally millions of acres have been made fit for agriculture through work founded on the knowledge of the life history of blood-sucking insects and blood parasites. Without the work of the biologist the Panama Canal in all probability could never have been dug or the area surrounding it made inhabitable—certainly not without a very heavy and continuing loss of human life from the ravages of yellow fever and malaria.

Biologists also solved the life-cycle secrets of the trichina worm in pork, which is so fatal if taken into the digestive system. The recent work of biologists on the various diseases of the

tropics has led to the opening up for civilization of large areas, particularly in Africa. In fact, the chief reason that parts of Africa still remind us of the "Dark Continent" is that the life cycles of many native destructive pests are as yet unsolved. At the present time many biologists, particularly those devoted to parasitology, are working on these and related problems.

Although hundreds of trained men and women have contributed an important share to the development of bacteriology and protozoölogy, it is to Pasteur, Koch, and Lister, working principally in the last third of the nineteenth century, that the greatest credit must be given. It would be difficult even to estimate the value of their contributions to social progress from the standpoint of health and of economics.

Every year important new contributions are made by protozoölogists, entomologists, and bacteriologists to the health of the human race. In the past two decades largely through the activities of biologists, at least ten years have been added to the average length of life of all people in civilized countries.

Due to the careful research work of biologists we now have vaccines and serums for the prevention of several diseases, particularly rabies, typhoid fever, smallpox, diphtheria, and tetanus (lockjaw). The saving in human life amounts annually to millions of lives in the case of these five diseases alone. The production of other serums capable of overcoming human and animal diseases is almost sure to be announced year by year. It is possible to say that every human disease, and also those of domestic and wild animals and plants, can be almost, if not entirely, eliminated if scientists are able to solve the life histories and life habits of animal and vegetable parasites. Preventive medicine is now one of the most promising fields of investigation and research.

As stated in an earlier chapter, one of the closest races ever run between two species for supremacy of any given territory is now being waged between man and the insects. Man has the great advantage in being able to think out and plan, whereas the insects have the great advantage of numbers. It

seems that only by continuing to study these pests scientifically shall we be able finally to win the battle. As the matter now rests, man has a slight advantage in most areas, but there are still places where it is impossible for either man (particularly the white man) or his domestic animals to live, notably in parts of Africa.

Within the past score of years only have we been fighting the house fly as one of the disease-carrying pests. With the spread of the knowledge worked out in this field, sickness and death from typhoid fever and tuberculosis have been greatly reduced. Cattle raising has again been made profitable in certain parts of Texas and of other states and countries because the life cycle of the cattle tick, and of the protozoa that it harbors, have been traced.

Likewise the citrus-fruit industry of the Pacific coast and Florida has been again made profitable because entomologists have worked out the life cycle of the cottony cushion scale and its destroyer, the lady beetle. The raising of hogs is again very generally profitable because the life cycle of the cholera germ has been traced and the appropriate immunizing serum produced.

It seems as if almost every year another serious pest is discovered, the control of which baffles for a time the best minds of the scientific world. Among the notable parasites now engaging attention are the European corn borer, the alfalfa weevil, and the boll weevil which devastates the cotton fields. As year by year man continues to increase in numbers and to occupy new territory, thus destroying old balances in nature, the problem of checking insect pests becomes more and more serious.

One thing is certain: uninterrupted study on the part of the biologist and other scientists is essential if these bacterial, yeast, mold, protozoan, worm, and insect pests are to be held in check. No one can estimate the great step backward that civilization would take if it were possible in a generation of time to blot out the work of the biologist. From present indications it seems as if his rôle in future civilization will be even greater relatively than in the past or present.

It is indeed fortunate that the science of biology has been able to contribute so largely not only to the field of pure science but also to the most practical phases of human life as well. The opportunities for profitable service to society in the field of biology are both innumerable and fascinating.

QUESTIONS

1. What would probably have happened to the death rate among the soldiers of the World War if we had not known that bacteria caused diseases?

2. What do you think kept scientists from discovering that bacteria cause diseases, until nearly two centuries after bacteria were first seen?

3. How has our relatively late knowledge of the habits of the fly increased the average length of human life?

4. How have the sciences of bacteriology and parasitology helped the farmer? The baker? The physician?

5. Why were the Greeks and Romans more often exposed to widely different parasites than any other peoples of their time?

6. Can you name a civic problem awaiting the biologist to solve?

7. Has the bringing of large groups of children and youths together in schools and colleges served to increase or to decrease the biological problems, particularly in reference to disease?

8. Can you name any biological advantage (in terms of disease) in having large groups of children play and work together?

9. In what other ways have the facts dealt with in this chapter made for better health and more effective health education?

10. What facts, if any, regarding bacteria and animal parasites could be profitably taught to children in the primary grades? In the upper elementary grades? In the junior high school? In the senior high school?

CHAPTER XXVI

OUTSTANDING EPOCHS IN THE HISTORY OF BIOLOGY

A brief account of six outstanding epochs and six leading men of biology, beginning with Aristotle.

If one is intelligently to interpret the facts and principles of biology and if one is to understand the relation of biology to the progress of mankind, one must know something about the way in which biological knowledge has developed.

Intellectually, the most advanced people of antiquity were the Greeks and it was among the Greeks that scientific knowledge—knowledge based on unprejudiced observation and experiment—had its origin. Of all the Greeks, Aristotle is held in highest esteem by the biologist, and rightly so. As is well known, Aristotle was the student of Plato, who in turn studied under Socrates. A better opportunity could not have come in ancient times to any scholar than that which was afforded to Aristotle.

Aristotle was employed by King Philip of Macedon to be the tutor of his son, Alexander, later called "the Great," soon to occupy a commanding place in the affairs of the then known world. Although Alexander, as history relates, had many characteristics certainly not in accord with modern standards, he had a highly redeeming characteristic, a profound respect for his teacher, Aristotle. It is asserted by some historians that he detailed at least one thousand men, in his world-conquering tours, to bring back to his old teacher the new animals and plants encountered. Whether the number be one thousand, two thousand, or only a few score of men, it is certain that many foreign species were brought to Aristotle and that he studied

them carefully. In fact, Aristotle's ability coupled with his interest in living things makes him the outstanding biologist of ancient times. Doubtless many of the beliefs that were current in Greece at that time are now attributed to Aristotle; nevertheless, his own contributions to biological knowledge were monumental. As we have seen (Chapter X) it was Aristotle who first attempted in a systematic way to classify plants and



FIG. 106.—Aristotle, 384–322 B. C. (From Locy.)

animals. He also made and recorded many keen and competent observations concerning the structure of plants and animals and the phenomena of reproduction, and he brought together what others had learned regarding these things. In this connection, it is interesting to note though that in his writings on biology he speaks of the “ancients” and what they believed about living things.

Aristotle lived from 384 to 322 B.C., and there is a gap of more than a thousand years before another prominent man or

movement appears in the field of biology.¹ Although there were a few prominent scientists in the centuries of the early Christian era, notably the great physician, Galen, one can say in general that very little progress was made for over a thousand years, largely because scientific research was hampered in various ways. Science has often been hampered, and not until the principle was established that scientific authority rests *only* upon demonstrated or proved facts rather than upon the opinion of some human being, even of high station or high reputation, was there much progress. Truth never needs the support of false props. The aim of science is to find the truth, regardless of the cost or consequences.

Although great men, such as Galen (131–200 A.D.), Averroës (1126–1198 A.D.), and others lived and contributed to the knowledge of the biology of their day, no great new epoch was opened until about the year 1590, when Jansen of Holland made the first compound microscope. While the scientific study of microscopic life did not make much progress until nearly three centuries later, when its connection with disease was discovered, yet it is obvious that this single invention opened the possibility of the study of a totally new world.

A name justly associated with the early use of the compound microscope is that of Anton van Leeuwenhoek (1632–1723), also of Holland, who constructed such an instrument about 1665 and discovered protozoa in 1675 and bacteria in 1683. Many others of only slightly less importance also used the compound microscope in the seventeenth century. Since Van Leeuwenhoek was the outstanding figure in the early use of the compound microscope, we shall use his name to head this important epoch in biological history.

One who stops to reflect upon the condition that we would

¹ It should be kept in mind that the word "biology" did not come into use until about the year 1810, although a science of living things had long been recognized. Although life of various kinds was studied, thousands of years prior to this date, it was not until long after the beginning of the nineteenth century that the present term, "biologist," was applied to the person pursuing this study. Prior to this date and for many years afterward he was designated merely as a "scientist" or, more usually, a "naturalist."

be in if we did not have the compound microscope will be in a position to recognize our indebtedness to Jansen and Van Leeuwenhoek. None of the bacteria, yeasts, molds, protozoa,



FIG. 107.—Leeuwenhoek, 1632–1723. (From Locy.)

or other minute life-forms would be known. We should still be giving superstitious or mythical answers as to how decay and fermentation take place. We should know nothing about cells

and almost nothing about the more minute structures of plants and animals. The sciences of embryology and genetics would be almost if not entirely unknown. Medicine would still be founded mostly upon hearsay and upon the "authority" of the ancient

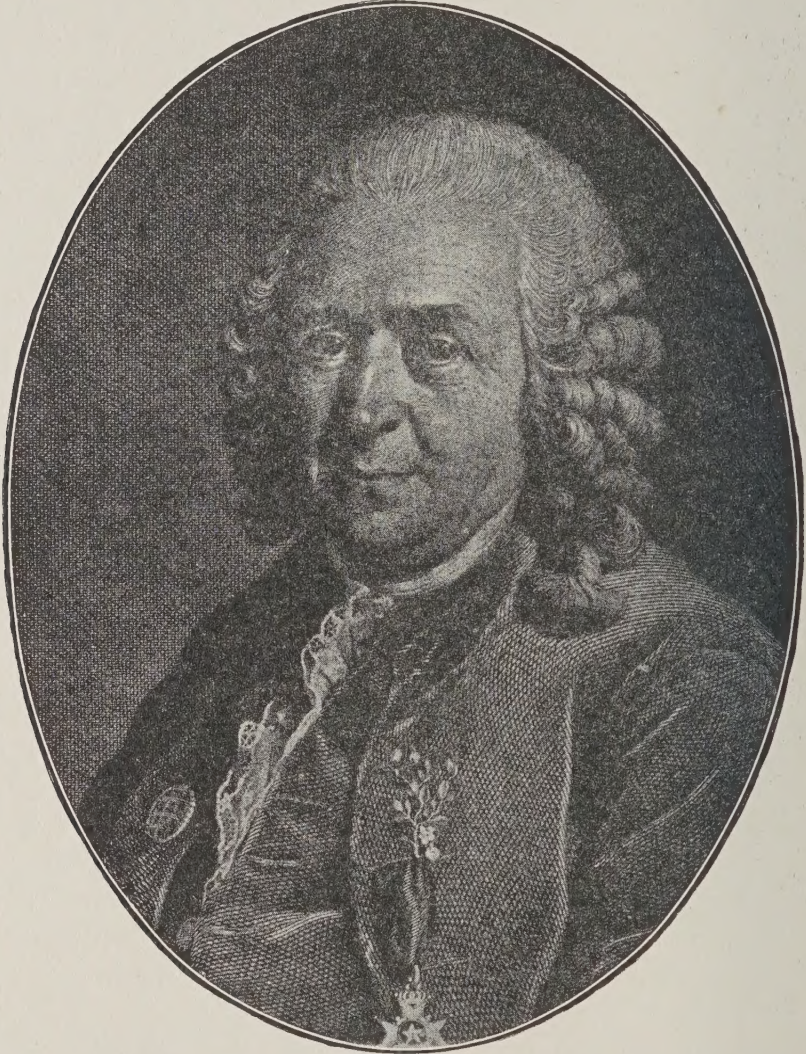


FIG. 108.—Linnaeus at sixty, 1707–1778. (From Locy.)

physicians. Even so brief and incomplete a survey as this indicates that biology would be in a sorry plight without the microscope. It would be difficult to name any implement or machine that has had a more profound effect on the human race. Certainly the telescope, although of great importance, dis-

covering for us many new worlds, hardly compares with the microscope in its contribution to the health and happiness of man; nor does the mariner's compass; perhaps only the printing press falls in the same category.

Nearly a century after the discovery of bacteria, another great advance was made in biology. This was the epoch-making work of the famous Swedish naturalist, Linnæus (1707-1778), in the field of taxonomy or systematic biology. His first important work was published in 1737, but it was not until 1753 that his monumental treatise on plant life was published, and in 1758 his equally great work on animal life. The significance of the system of classification devised by Linnæus has been referred to in a preceding chapter. (See Chapter X.) After many attempts at classification based on various concepts, the scientific world has universally adopted the method proposed by Linnæus in 1753. It is almost needless to say that minor rules have been since adopted and slight changes made in the Linnæan system, yet the central idea of this great scientist still persists.

With a practical and successful scientific system of classification, such as the binomial system of Linnæus, scientific men of the whole world are able to converse intelligently about any animal or plant that they wish to discuss. Without this or an equally good system of classification, the naming and description of animals and plants would be in deplorable confusion.

The next great leader of a great movement in biological thought was Charles Darwin, born Feb. 12, 1809, on the same day, by an interesting coincidence, as Abraham Lincoln. By many these two are thought to be the two outstanding men of the nineteenth century. One liberated millions of men from physical slavery, the other, millions from the mental slavery of tradition and unproved facts, particularly concerning the origin and preservation of species. Darwin, although handicapped by delicate health, did an enormous amount of work in several fields, but his name is most often associated with the doctrine of evolution.

Without the concept of evolution, it is difficult to say what the condition of biology—or, indeed, of any science—would be to-day. The whole idea of evolution so permeates every division of the wide field of biology, that it may justly be regarded as the central idea upon which rest all of the modern sciences which

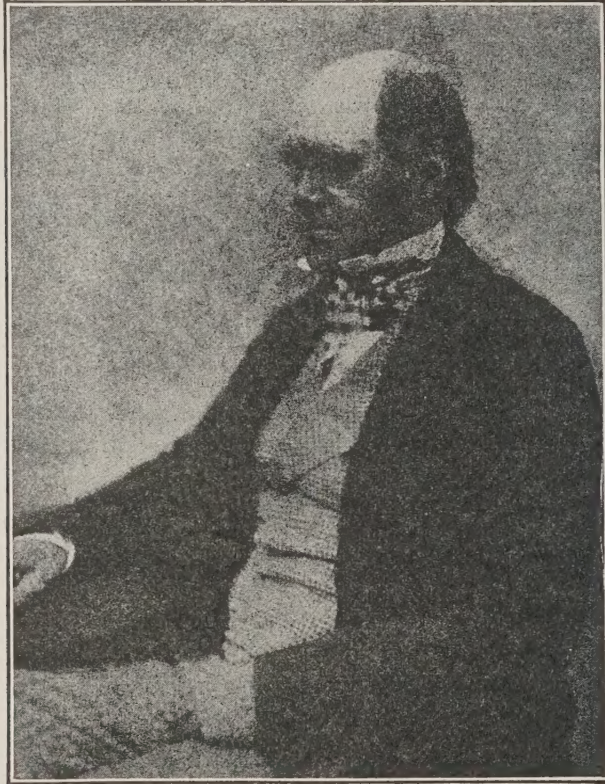


FIG. 109.—Charles Darwin, 1809–1882. (From Locy)

deal with life. There is no biologist of repute who does not consider the evolutionary hypothesis the most reasonable and logical explanation of the way in which the various genera, species, and varieties of plant and animal life have come to be what they are. The entire world is under a great debt to this profound thinker, although some are unaware of it. If he does not rank first in the minds of most biologists, he certainly would be classed as one of the half-dozen greatest by almost every person who has made himself competent by study and research to pass judgment.

Working at the same time that Darwin was producing some of his best books was another man, named Mendel, who lived in an out-of-the-way place at Brno in Moravia, formerly an Austrian province, now a part of Czechoslovakia. There are few biologists to-day who would deny Mendel the honor of

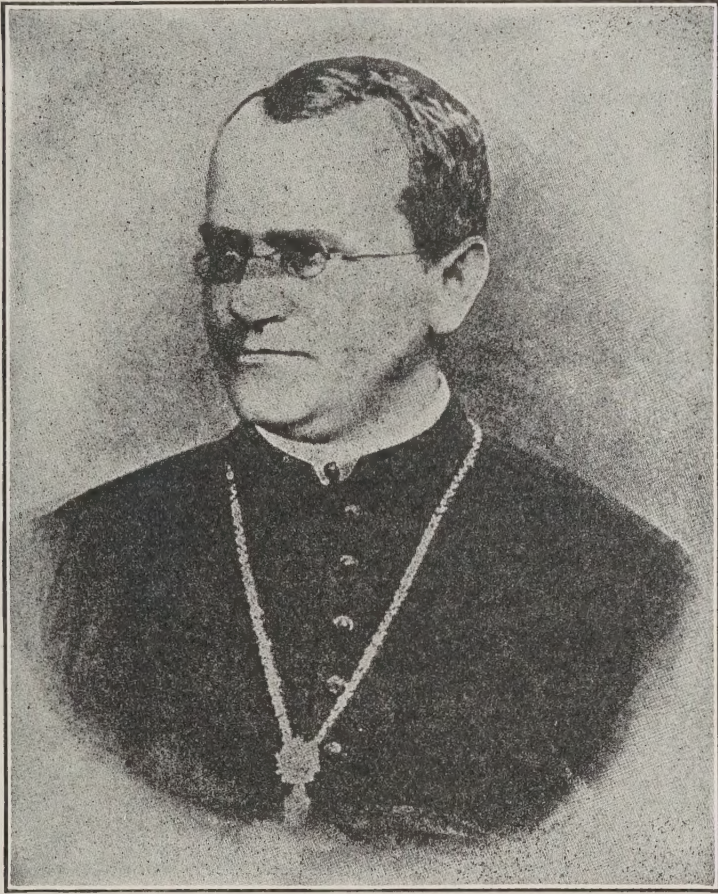


FIG. 110.—Gregor Mendel, 1822–1884. (From Locy, with permission of Professor Bateson.)

opening and representing the great field of heredity, or genetics, as it is now called. Although his published records were not rediscovered until 1900, he performed most of his experiments and wrote his paper giving his findings in the decade from 1860 to 1870. That a man, apparently not trained as a scientist, should have had the insight to think through, and the technique to carry out, such experiments as his seems almost incredible.

As we have seen (Chapter XXI), additions have been made to the laws formulated by Mendel; yet in the main his work as first related stands every test. It was a masterpiece of the first magnitude, opening up a wholly new field of biological research,

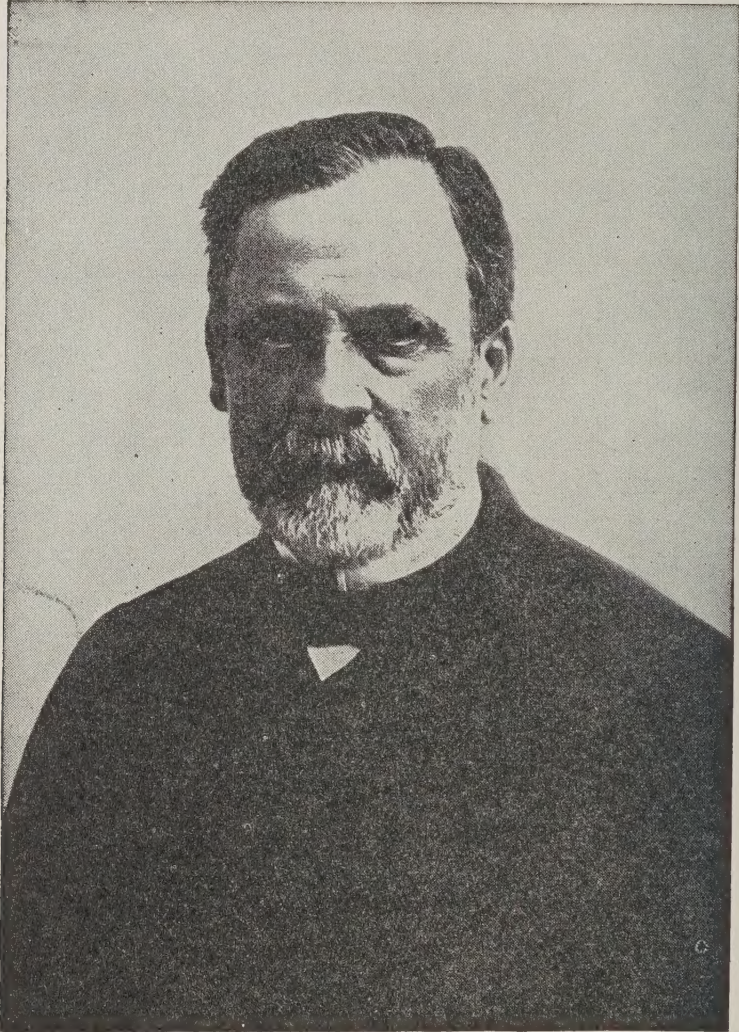


FIG. 111.—Louis Pasteur, 1822–1895. (From Locy.)

the field that should be the most interesting of all since it concerns directly ourselves, our posterity, and the animals and plants that we have domesticated. Gregor Mendel will doubtless always remain as one of the outstanding figures in the history of science.

The last great name that will be mentioned is that of Pasteur, voted by the French nation in 1925 as the greatest man that his country has yet produced, and rightly so. Pasteur's fame rests not at all on military or political deeds but entirely on scientific work which rendered great service not only to the French nation but to the human race as a whole.

Pasteur was born in France in 1822, and as a youth did not seem to show unusual ability. His later life is so well known to millions as to need no comment here. Certainly there was no one during his day who exemplified in a higher degree the skill, insight, and constructive imagination that are essential to scientific research of the first order. Although many men had a part in demonstrating the fact that numerous diseases are caused by bacteria and protozoa and that fermentation and decay are caused by minute organisms, Pasteur was the real pioneer in these epoch-making discoveries. In honoring Pasteur, one should not forget the great work of Lister of England in antiseptic surgery, of Koch of Germany in the study of disease-producing organisms, and of others less famous. Those men will also always occupy a distinguished place in biological history.

Perhaps the work of Pasteur that commanded, more than any other, the attention of the world was that on rabies or hydrophobia. Probably several million persons throughout the world have already been saved from a terrible death by the various kinds of antitoxin that have been developed as a result of Pasteur's studies.

Even at the present writing it is impossible to estimate the great value to mankind of the scientific investigations of Pasteur and his contemporaries. Most of the means now taken to prevent and cure diseases rest at basis upon the discoveries of Pasteur. The economic value to the world of the knowledge regarding the process of fermentation and decay is inestimable and it was Pasteur who first laid bare the facts.

Six great men have been mentioned, representing six great epochs in biological history. One lived in the fourth century before the Christian era, one in the seventeenth century, one in

the eighteenth century, and three in the latter half of the nineteenth century. This indicates that most of the work in biology has been done in relatively recent times. In fact it would be comparatively easy to prove that more sound biological facts and principles were discovered in the nineteenth century than in all time preceding. Nor has the interest in biological investigation slackened during the first quarter of the twentieth century; on the contrary, it steadily increases its momentum.

Since the majority of those who contributed to the biological advancement of the twentieth century are still living, and since there has been too little time as yet to get the proper perspective on their work, no names of the great biological investigators of this the twentieth century will be mentioned. One may venture to predict that history will record more great biological discoveries in the twentieth century than in any preceding era.

The choice of the six greatest biologists of all time just discussed, may not meet with universal approval, and some biologists may wish to substitute the name of one other for one given, leaving the other five; but that is not a serious matter. All would agree that the six named were mighty men in the field of biological investigation. Certainly another six of equal importance could not be named, although the embryologist might wish to include von Baer and the physiologist Galen or Harvey. However, the writer will rest the case by saying that to him Aristotle, van Leeuwenhoek, Linnæus, Darwin, Mendel, and Pasteur are the outstanding figures in biological history, with a score of others meriting very high praise.

Although the fact is of no great scientific significance, it is interesting to note that no nationality contributed more than one man to this illustrious group. The great masters were, in turn, a Greek, a Hollander, a Swede, an Englishman, a Czech, and a Frenchman. This speaks well for the universality of science.

It is likewise interesting to note that scientific achievement is not the possession of any one sect or religion, since Aristotle was a "pagan" (he lived nearly four centuries before the birth

of Christ), van Leeuwenhoek was a Lutheran, Linnæus a Lutheran, Darwin an Episcopalian, Mendel a Roman Catholic, and Pasteur a Roman Catholic. Science honors anyone, regardless of race or creed, if he contributes to the advancement of truth. The language of truth is a universal language.

To the teacher of the common-school branches and of special subjects other than biology, parts of this chapter may seem to contribute little of value to understanding or solving the problems of the schoolroom. To a degree this is true, except that every teacher should know the outstanding men and epochs in all branches of learning. If the teacher cannot name a few great musicians and tell what they composed, if he knows none of the great artists or sculptors, if he knows none of the great men of letters, if he knows none of the great religious leaders, he certainly does not have the broad background of information and interpretation that every teacher should have.

However, two of these men represent such important phases of modern education, even in the elementary grades, that an ignorance of their names is hardly excusable. They are van Leeuwenhoek and Pasteur, who are primarily responsible for our emphasis on health and the prevention and cure of disease. A study of the life of Pasteur¹ particularly is not only of interest and of value to the scientist but is truly thrilling, as fascinating as a fairy tale.

QUESTIONS

1. In what way did Aristotle's writings serve to impede the progress of science? How did he help science?
2. Why do you think the early Christian teachers forbade the open thinking and doing of things now commonly thought, done, and accepted by the same type of teachers, as well as by scientists?
3. How many fields of endeavor has the invention of the compound microscope affected? Name them.
4. Why do you think that biologists failed to work out the system of classification of living things according to structure before the time of Linnæus in the eighteenth century?

¹ See any encyclopedia, or biography of men of science, or Vallery-Radot, René, *The Life of Pasteur*. Doubleday, Page and Co., 1916.

5. Name the fields of human endeavor that Darwin's doctrine of evolution has materially affected.

6. Name several ways, other than those listed in the chapter, in which Pasteur's work benefited mankind.

7. Why did the science of heredity have to await the discovery of the maturation of the egg and sperm cells, by van Beneden in 1883, before it could make much progress?

8. Stories of great soldiers and great political leaders are an important part of the curriculum of the elementary school. Do you think that it would be a good thing to tell to the younger children the stories of Aristotle, Darwin, van Leeuwenhoek, Linnæus, Mendel, and Pasteur as representing outstanding heroes in the field of human advancement?

9. If so, in what grade or grades should each of these persons be introduced?

CHAPTER XXVII

THE BRAIN

The master tissue—Its evolution from lower forms to man—The increase in size, texture, and importance of the cerebrum.

In Professor Frederick Tilney's ¹ two-volume book, *The Brain from Ape to Man*, there are many significant statements regarding the brain and its functions. From the point of view of the purpose of this book, a few of the more important statements may well be quoted:

"The brain is conceded to be the master organ of the body, the regulator of life, the source of human progress. In this capacity how has it contributed to the evolution of mankind? Has it, as some authorities assume, passed through successive evolutionary stages to reach its highest development? Both of these questions imply the acceptance of the Evolutionary Theory. If this hypothesis be correct, the human brain should prove an important witness in its favor. It may be expected to retain conclusive evidence of the evolutionary process in at least three particulars.

"1. It should manifest signs of its primitive origin from the lowest vertebrates.

"2. It should bear identifying marks of intimate association with animals of its own class, the mammals.

"3. It should also have many specific details in common with members of the Primate Order, to which man belongs, together with lemurs, tarsiers, monkeys, and apes."

Again, on another page, the following:

"The reasons why the brain contains the most comprehensive record of the evolutionary process are readily perceived. As an

¹ Tilney, F., *The Brain from Ape to Man*. Paul B. Hoeber, Inc., New York, 1928.

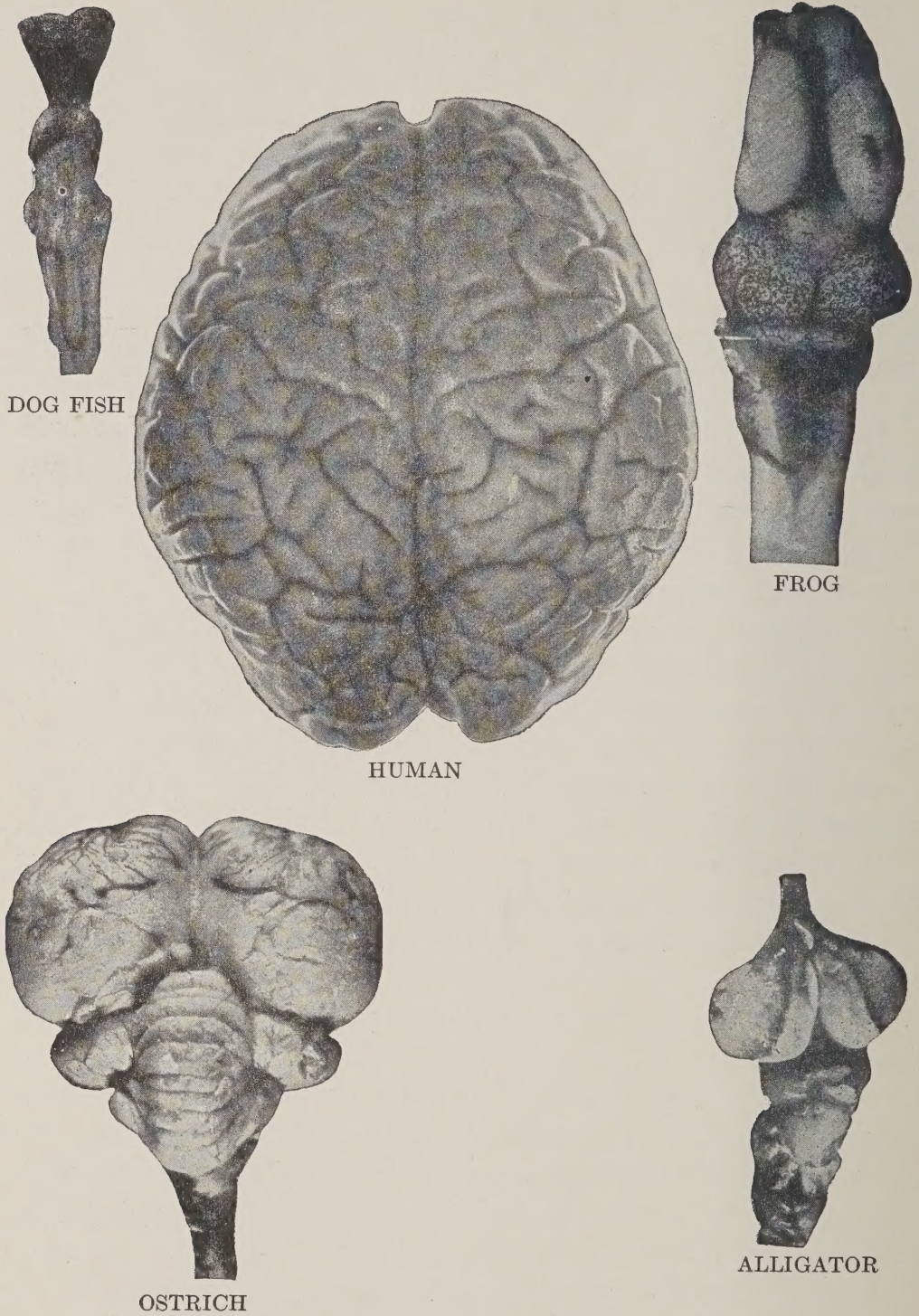


FIG. 112.—Brains of lower invertebrates compared with the human brain.
 (After Tilney's *The Brain from Ape to Man*, Paul B. Hoeher, Inc.,
 1928.)

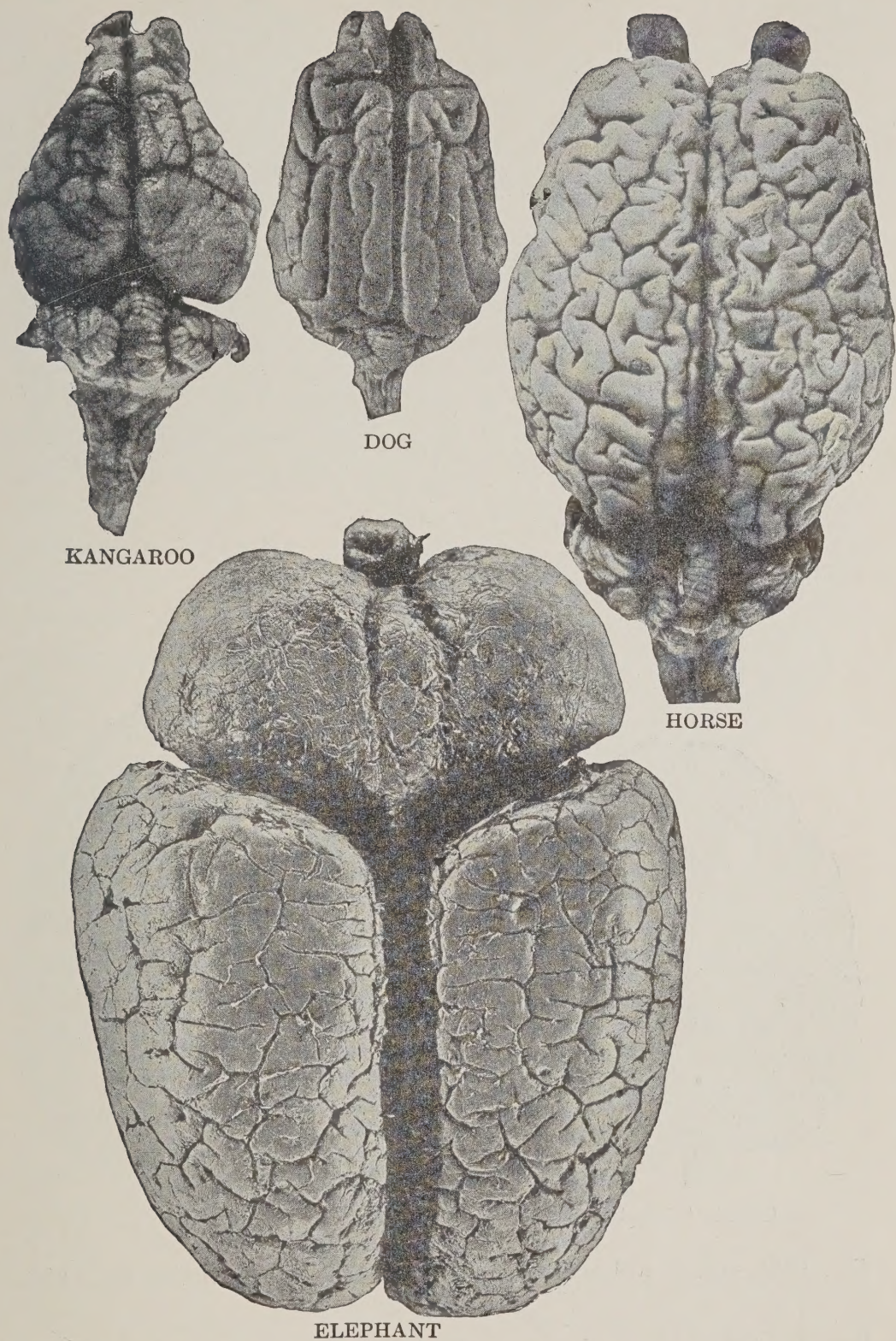


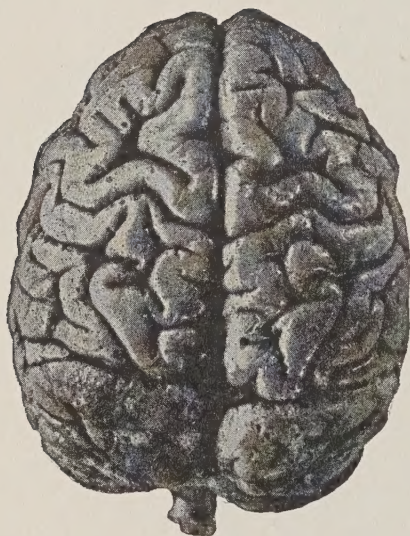
FIG. 113.—Brains of mammals. Compare with the human brain in Fig. 112.
(From Tilney.)



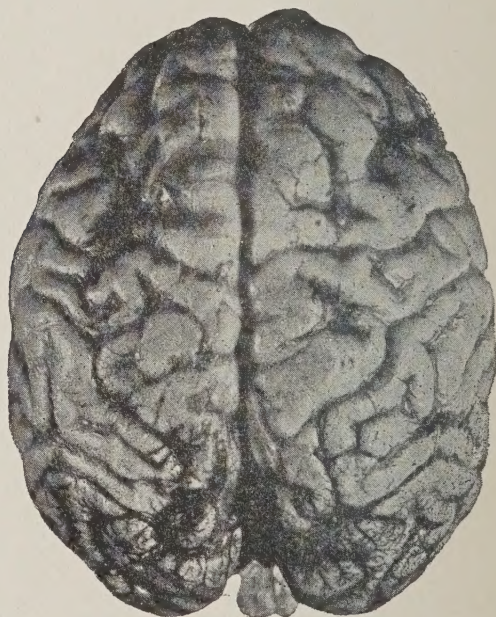
BABOON



GIBBON



CHIMPANZEE



GORILLA

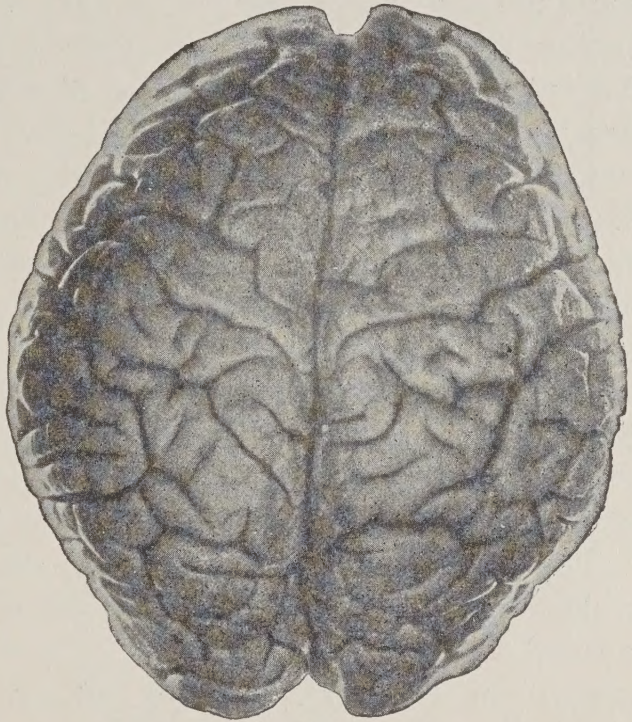
FIG. 114A.—Brains of apes. Compare with the human brain, Fig. 114B.
(From Tilney.)

organ its influences pervade and dominate all other systems of the body. It is the great transformer of energy which integrates all parts into a harmoniously acting machine. It interprets all impressions from without. It projects all impulses from within.

In its *dual capacity of servant and master* the brain has been peculiarly susceptible to the influence of that combination of factors described by Professor Osborn in his tetraplastic theory of evolution. The *cerebrum* has felt more, perhaps, than any other organ, the effects of action, reaction, and interaction. It has responded more extensively to its inorganic and vital environment because it comprises the *most highly differentiated tissue* of the organism. It has been equally sensitive to the influence of heredity . . . and . . . environment."

Still again, these significant paragraphs:

"Since brain power admittedly is the secret of human success, the brain itself must be the pioneer, hewing the path of man's progress; hence the genesis of this dominant organ is a vital issue which calls for most intensive research. The answers to the questions 'whence came the brain and how' have become indispensable to modern understanding. Their value lies in the light thrown by them upon the course of man's long ascent and in their searching penetration through the dense veil which hides his future.



HUMAN

FIG. 114B.—(From Tilney.)

"Upon directing our attention toward the future, there are many reasons for asking whither we are tending as a race. Does the path lead forward through repetitious ancient cycles of disaster, toward wars and revolutions, toward civic frustrations amid the preparations for future wars in times of peace, toward further stupidities in the management of social organizations, toward grosser misconceptions of man and humanity, toward greater depths of superstitious delusion and human unworthiness with their full and final penalty of ultimate extinction? Catastrophe such as this has not infrequently overtaken many races of men long since extinct. *It is possible, however, that the supreme organ which created what there is of human succeeding has still further benefits to confer.*"

Although it appears now that the highest forms of life, and particularly man, depend far more upon the brain than on any other tissue of the body for their survival as a species, it should not be thought that this was always so with all species.

The giant reptiles, particularly the extinct dinosaurs (casts of which are so prominently displayed in large museums), depended far more upon their great bulk to preserve their species than upon the brain. In some of these reptiles weighing well over ten tons the weight of the brain was only a very few ounces. Indeed in one extinct species, *Diplodocus carnegii*, weighing from twenty to forty tons, the brain was scarcely larger than the thumb of a man's hand. One visiting a museum showing the skeleton of one of these giant reptiles will be impressed by the insignificant size of the brain case.

Nor is it to be supposed that the lack of quantity of brain in these reptiles was in some way made up for by a high degree of quality. There is not the slightest evidence for such an assumption. Brute strength apparently was their chief defense against extinction, and this in the long run was unsuccessful. In one sense, large size represents a high degree of specialization, but like many other specializations, it was successful only as long as the particular environment remained relatively fixed.

Considering long periods of time, as we have already seen

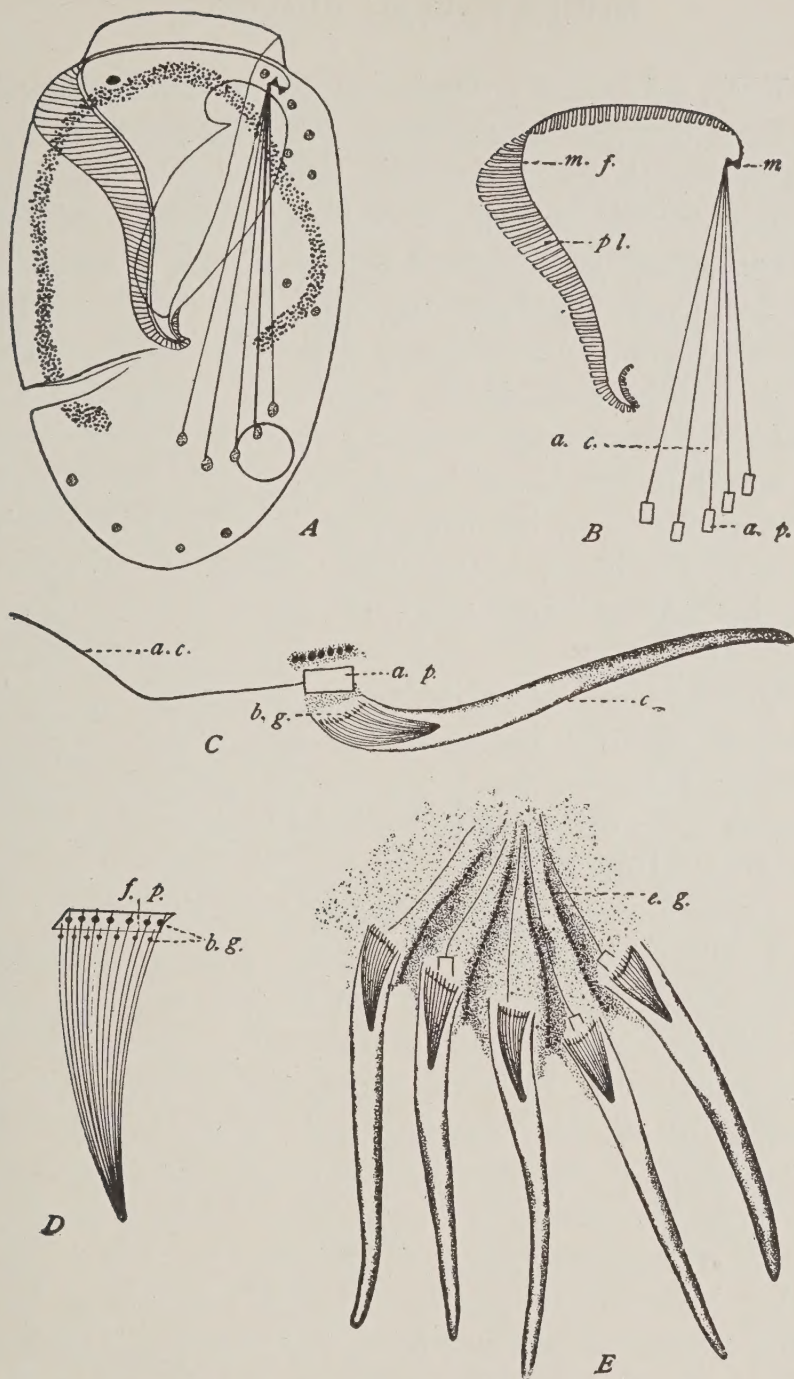


FIG. 115.—Micro-dissection of *Euplotes patella*. A, individual with lateral cut, showing distribution of the cellular structures; B, neuromotor apparatus isolated; C, an anal cirrus with accompanying structures; D, an isolated membranilla; E, the five anal cirri: (a.c.) anal cirri fibers; (a.p.) basal plates of the anal cirri; (b.g.) basal granules; (c) cirrus; (e.g.) ectoplasmic granules; (f.p.) fiber plate; (m.f.) membranelle fiber; (m) motorium; (p.l.) membranelle plates. (From Calkins, after Taylor.)

(Chap. XII), only those animals and plants that remained relatively generalized gave rise to the higher forms of life. It should be remembered that a generalized animal or plant can usually survive over a wider range and in many more varied environments than a highly specialized species of life. Were it not for the fact (see Chap. XII) that the brain does enable man to adjust himself to and in a measure control his environment, the master tissue, the most highly specialized tissue of all, might also lead him to eventual extinction. It seems that the tendency toward specialization has at last evolved a specialized structure that may prove to be its own corrective. Since the brain will doubtless play a larger and a larger part in human life, it is important that we know more about its formation and its evolution.

Far down in the scale of animal life, in some of the higher protozoa, we find the beginnings of a neuro-motor apparatus which seems to serve this protozoan in much the same way (only much more primitively) that the brain serves the higher animals (Fig. 115).

In the common earthworm (Fig. 116), we find a very simply constructed brain in the third segment from the anterior end. It is easily discernible from the outside as well as from the inside that the earthworm has many segments, usually exceeding one hundred in number. In some ways, each segment is almost independent of all the other segments, while in a number of other ways each is dependent upon the others and all form a single unit of life called the worm.

The central nervous system of the earthworm is exceedingly interesting because each segment has a ganglion of its own, which can operate almost independently, and yet it seems to be connected with all of the other hundred or more ganglia through the slightly larger ganglion of the anterior end, called the brain. Since the first two segments of the earthworm do not have ganglia, it is thought that the brain in the third segment really represents the three ganglia united into one and there is some experimental evidence that this is so. In size, the earthworm's

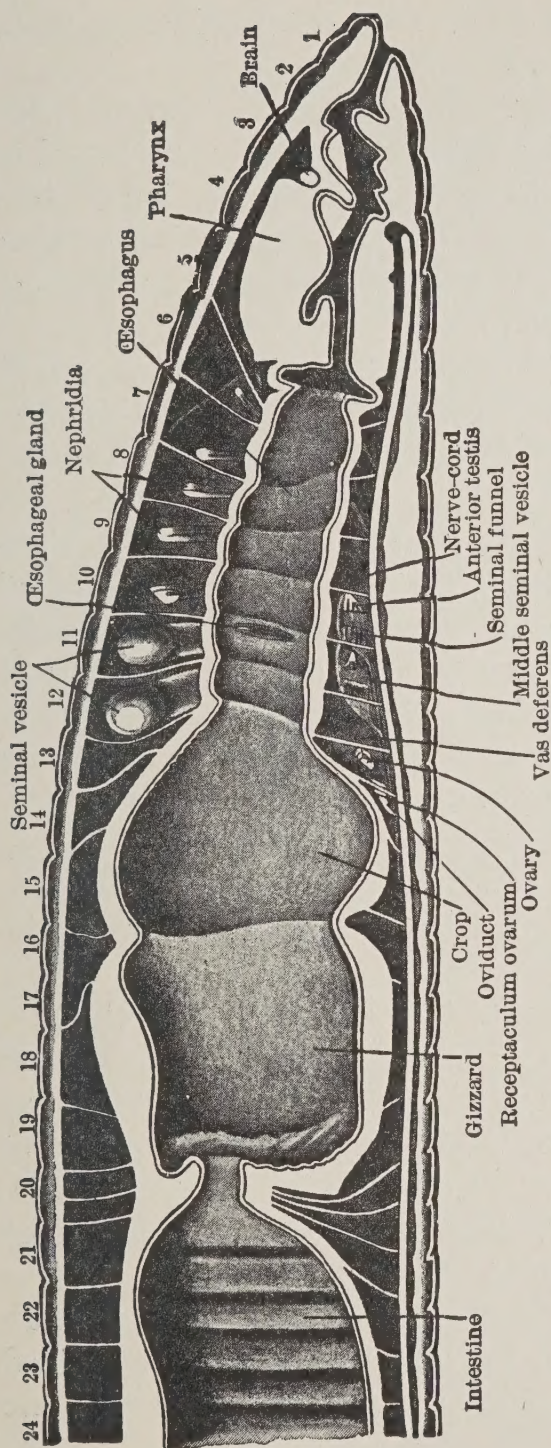


FIG. 116.—Longitudinal vertical section through the anterior portion of an earthworm. (From Hegner, after Marshall and Hurst.)

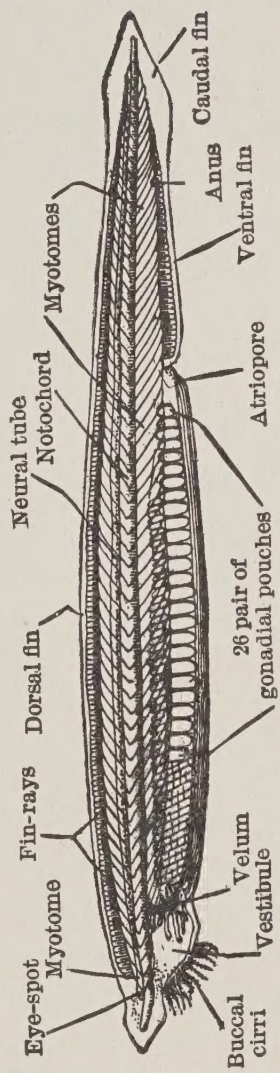


FIG. 117.—An adult specimen of *Branchiostoma lanceolatus*, seen from the left side as a transparent object. (From Hegner, after Bourne.)

“brain” is only a few times larger than the ganglion found in each of the other segments.

In morphological structure the brain of the earthworm is not so well differentiated into the highly specialized parts found in the higher animals. Perhaps because it is slightly larger than the rest and also because of its location at the anterior end near where the food is taken in, it may exercise some measure of control over the other ganglia.

As animal life ascends in complexity from the annelids, which include the earthworm, through the molluscs, the arthropods, and the vertebrates, one finds the brain taking on added significance.

In the lower species of the vertebrates, the brain is still relatively simple, as in *Amphioxus* (Fig. 117). This is an animal ordinarily only a few inches in length, which looks externally much like a fish, yet in many ways differing greatly. Most of the fishes have a rather prominent brain and brain case, yet in *Amphioxus* the brain case is lacking and the brain is only an enlarged anterior segment of the central nerve-cord. Indeed, most zoölogists think it too simple to be dignified by the term, brain, so they call it the *cerebral vesicle*. Of course it is much more complex in structure than the enlarged ganglion of the earthworm already referred to.

Only as one ascends to the highest sub-phylum of the vertebrates or Chordata does one find the brain becoming well differentiated structurally from the rest of the central nervous system. In this sub-phylum zoölogists usually place, in order of their ascending complexity, the following classes: the *Cyclostomata* (example, lamprey eel), the *Elasmobranchii* (example, the shark), the *Pisces* (fishes), the *Amphibia* (frogs), the *Reptilia* (snakes), the *Aves* (birds) and the *Mammalia*. Allowing for an occasional degenerate family, the brain clearly takes on added complexity of structure and significance of function as one approaches the Mammalia.

In the *Cyclostomata*, which comprise the lampreys and the hags, fish-like vertebrates without jaws or lateral fins, the

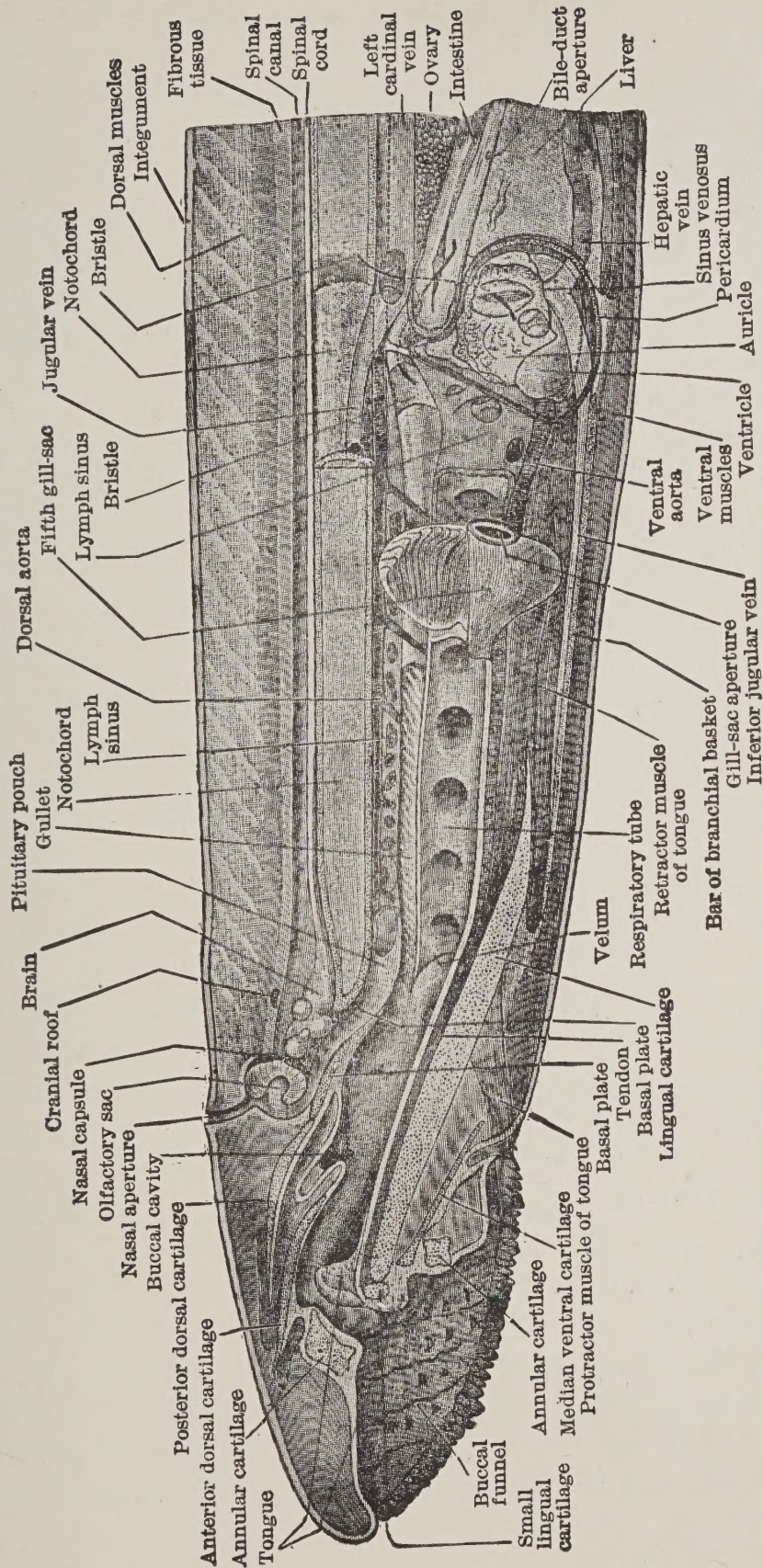


Fig. 118.—*Petromyzon merimiss*. Dissection of female. The cartilaginous parts and sheath of notochord are dotted. (From Hegner, after Parker.)

cranium is very simple in structure as is also the brain. It has no jaws, scales, true teeth, nor bones of any kind, only a persistent cartilaginous notochord (the forerunner of the backbone). Although simple, when compared to the higher class of vertebrates, the brain is probably more highly developed and of greater significance to the species, than in any of the lower

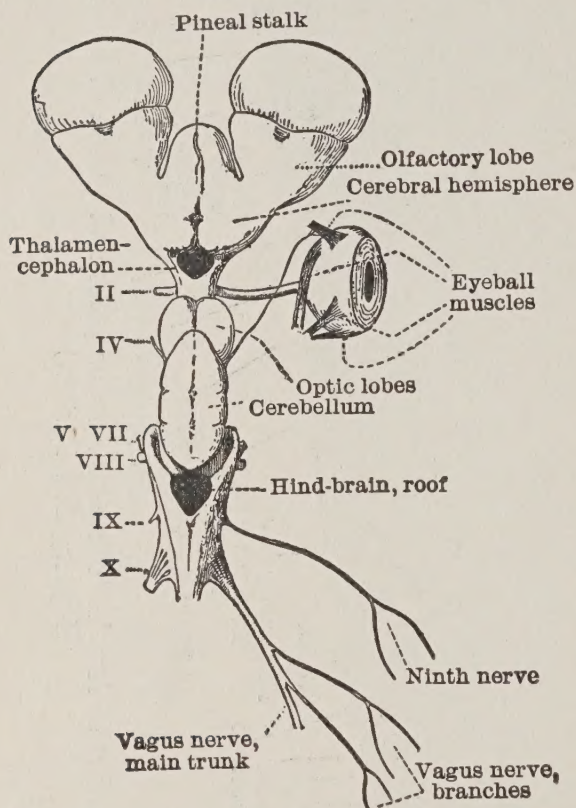


FIG. 119.—Brain of a dogfish shark, *Scylium catalus*, dorsal view. (From Hegner, after Shipley and McBride.)

phyla or classes. The anterior segments of the neural cord are considerably enlarged and show distinct parts, foreshadowing the complicated brain of the higher vertebrates (Fig. 118).

In the *Elasmobranchii*, which comprise the sharks, rays, and chimeras, fish-like vertebrates with jaws, a cartilaginous skeleton, and a persistent notochord, the skull is much more highly developed. In fact, for the first time there is a definite brain case, called the *cranium*. The brain is correspondingly developed.

The walls of the segments become thicker; the neural tube smaller; the segments themselves become distinct lobes. The parts of the brain discernible are the *olfactory lobes*, a *cerebrum* of two hemispheres, a pair of *optic lobes*, and *cerebellum* which projects backward over the *medulla oblongata*. The olfactory lobes are, in most species, by far the most prominent parts of the brain (Fig. 119).

In the *Pisces*, or true fishes, the jaws, bony skeleton, and the backbone are prominent, as is also the brain. Again the

brain is well differentiated into several parts, the *olfactory lobes*, the *cerebrum*, the *optic lobes*, the *cerebellum*, and the *medulla oblongata*. Both the olfactory and the optic lobes are now relatively less prominent; the cerebellum is relatively more prominent.

In the *Amphibia*, comprising the frogs, toads, and salamanders, the class next higher than the true fishes, the head and

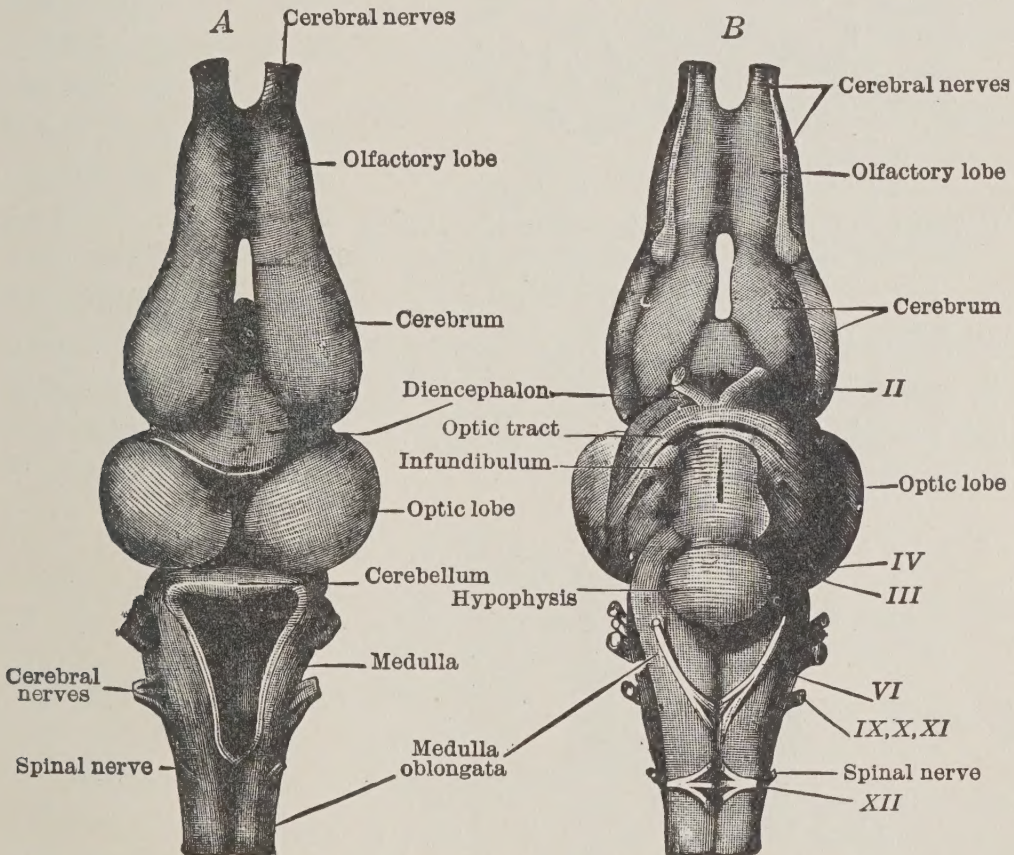


FIG. 120.—Brain of a frog. A, dorsal aspect. B, ventral aspect. I-XII, nerves. (From Hegner, after Wiedersheim.)

cranium are even more fully developed than in the fishes. This is also true of the brain (Fig. 120).

In the *Reptilia*, comprising the lizards, turtles, tortoises, alligators, crocodiles, and snakes, we find a still higher class of vertebrates. The skull is well developed and firm and the brain is also more highly developed than in the *Amphibia*. The

prominent parts are, the *olfactory lobes*, the *cerebral hemispheres*, the *optic lobes*, the *cerebellum*, and the *medulla oblongata* (Fig. 121). The cerebellum is distinctly larger than in the Amphibia, as are also the cerebral hemispheres. The various sense-organs are probably more highly developed on the average than in any

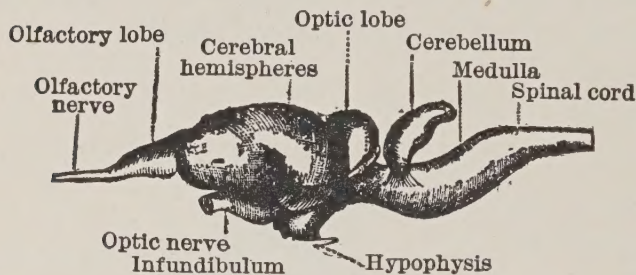


FIG. 121.—Side view of brain of a turtle. (From Hegner, after Wiedersheim.)

of the lower forms of life, particularly the organs of sight, hearing, smell, and touch.

In the *Aves*, or animals with feathers, we find the next to the highest form of vertebrate life. The jaws are usually prominent

and sometimes highly modified; the skull and cranium are highly developed, ordinarily very light, to enable them better to navigate the air. The brain is also greatly differentiated, divided into the following parts: the *olfactory lobes*, the *cerebral hemispheres*, the

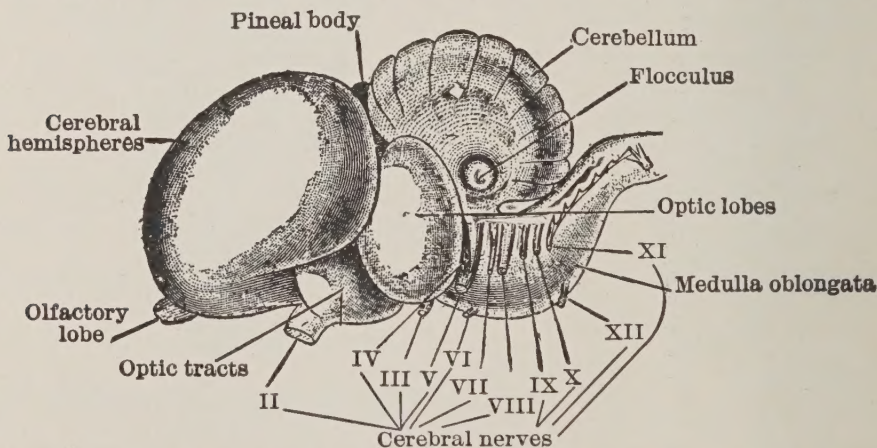


FIG. 122.—The brain of the pigeon, side view. (From Hegner, after Parker and Haswell.)

optic lobes, the *cerebellum*, and the *medulla oblongata* (Fig. 122). The cerebellum again is particularly well developed, with the cerebral hemispheres more prominent, on the average, than in the Reptilia.

In the *Mammalia*, or animals with hair and whose young are nourished by milk, we have the highest form of vertebrate life. These animals have prominent heads and well-developed brains, when considered as a class. (Like almost all other classes, occasionally a species is found with a poorly developed brain.) The outstanding parts of the mammalian brain are the *cerebral hemisphere*, the *cerebellum*, the *medulla oblongata*. In some species, the *olfactory bulb* is fairly prominent. The cerebrum, however, is by far the most prominent and highly developed (Fig. 123). Since the cerebrum seems to be particularly associ-

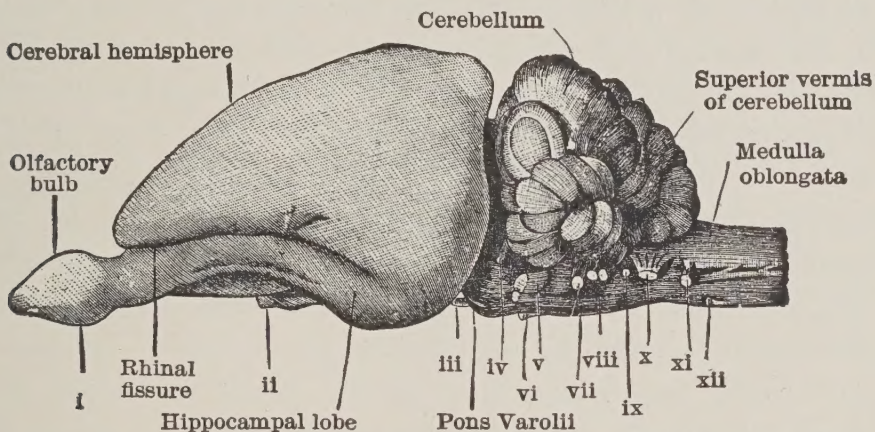


FIG. 123.—Side view of brain of the rabbit. (From Hegner, after Wiedersheim.)

ated with voluntary action, it is thus obvious why the mammals are spoken of as the most highly developed animals.

The very highest form of mammalian life, *Homo sapiens*, has a particularly large and well-developed cerebrum. Indeed it is so large as to overlie all the other parts of the brain.

Of course mere size does not alone necessarily indicate a highly developed brain, for if so the elephant and some whales would be more intelligent than man since their brains actually weigh more than the brain of man. (Cf. Chapter XII.) Although the human brain is very large, yet it is evident that man's superiority must rest upon the functions of the cerebrum rather than upon its size. Careful study shows that, wherever research workers have been able to show correlation between the struc-

ture of the brain and its mental functions, man's brain is the most highly developed. Externally man's brain shows a great number of deep convolutions. Internally the neuron connections with the muscles and with the sense-organs are more numerous and more favorable to elaborate combination. Indeed it seems that the superiority of man's brain may be found to a large extent in the very delicate and intricate way in which the numerous neurons can be brought into functional combinations. Just how a stimulus travels over the nerve fibers is not positively known, yet it seems as if it must be over these fine neuron fibers which are almost but not quite connected at their tip ends. The almost innumerable branchings of these fibers make possible an almost infinite number of functional connections.

When one considers the animal kingdom as a whole, it is safe to make the following generalization: As one ascends in the scale of the evolution of animal life, one finds that the brain has evolved proportionately both quantitatively and qualitatively. At birth the brain of the human child is very large, much larger proportionately than at any subsequent period. In fact the infant's brain grows only four or five times in weight before reaching adulthood, whereas the entire body increases from fifteen to twenty times. Since we now know that the infant at birth or very soon afterward has all the brain cells and indeed the identical brain cells that he will have when an adult, it is obvious that the greatest change as he approaches adulthood must be qualitative or functional. Indeed it is well known that the "texture" (not the "structure") of the brain changes materially during childhood and youth, particularly in the interconnections and coördinations of the neurons and their numerous delicate fibers.

We have thus seen that more and more the higher forms of life rely on the central nervous system, more particularly the brain, to keep both the individual and the species in existence. Indeed, "highness" or "lowness" in the scale of animal life from the lowest chordates on is very largely determined by the degree of the development of the brain. While all the other

tissues of the animal body are of importance, yet the most important tissue of all is the nervous tissue, and more particularly the cerebrum, of the central nervous system. Indeed the one who called the nervous tissue the "master tissue" made an important statement and generalization; to continue the figure of speech, one may well agree with Professor Tilney that, in the highest animals, the brain is the "master organ."

QUESTIONS

1. Why has an animal species with a well-developed brain a better chance of survival, ordinarily, than an animal with large size but small brain, *i.e.* considered over long periods of time?
2. Is there a probability that the brain may become too specialized? Why or how?
3. In the human being, is the development of the brain usually closely correlated with the development of the body?
4. What one great advantage has the specialization of the central nervous system of man (the brain particularly) over the other specialized organs of man which may keep the human species from extinction because of over-specialization?

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